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Beyond the Milky Way*

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Before we can appreciate this topic it is necessary to understand precisely what is meant by the term "Milky Way," and how we can know when we are "beyond" it. Initially it is simple to define the Milky Way as the faint band of light which can be seen on clear nights to extend completely around the whole sphere of the sky, and which telescopes have resolved into myriads of faint stars. As we shall see, the term has come to mean more than just what we can see; to some extent it is synonymous with the term "galaxy," which describes our concept of an organized system of stars, diffuse clouds of gas, and other material, inside of which we are located, and the study of which has occupied astronomers for several decades and will probably occupy them for several decades to come.

Why should these faint stars be distributed so peculiarly, as if in a doughnut-like ring around us? A simple interpretation comes to mind if we assume, for the moment, that all stars are intrinsically of about the same brightness. Then these faint stars of the Milky Way would be farther away than the brighter stars, their apparent brightness being less the more distant they are. (The apparent brightness of a luminous source is known from other considerations to be inversely proportional to the square of the distance.) Although refinements are necessary, this simple deduction from an unproven assumption is one of the basic methods for measuring astronomical distances. We must investigate further these distances and their measurement before the term "beyond" can have any meaning.

Astronomical distances are well recognized to be considerably larger than the distances we are familiar with; it is quite impossible to comprehend them in an absolute sense. But since we are concerned here only with one thing being "beyond" another, an appreciation of the *relative* sizes of various distances is sufficient. To avoid large numbers, it is convenient to use large units of distance: the "astronomical unit," which is about one hundred million miles (accurately the distance to the sun), and the "light year" (some 63,000 astronomical units—or the distance light travels in one year).

The most basic method of measuring distances between astronomical bodies (where it is impossible to pace out, or scale off, a distance, as

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we can do on the earth) is triangulation, a method used by surveyors, and familiar to most of you. It depends only on the validity of the axioms of Euclidean geometry, from which the lengths of the sides of a triangle can be deduced if one side and two angles are given (or measured), and the applicability of those axioms to rays of light. Observations from the two ends of a "base line" on the earth itself can thus be used to measure the distances to the nearby members of the solar system—to the moon, sun, planets, and comets—to anything, in fact, within about 50 astronomical units, beyond which the angles involved are too small to measure. Now since the earth goes around the sun in on orbit of known dimensions, this "parallax method" can be vastly extended, by using the diameter of the earth's orbit as base line, to determine distances to stars as far as 500 light years away. Still, the parallax method is too limited; almost all of the faint stars of the Milky Way seem to be considerably farther away than 500 light years.

Returning to the "brightness method" of measuring distance, we are disappointed to discover (after a few hundred star distances are measured by the parallax method) that our assumption of the stars being all of the same intrinsic luminosity was a poor one; some stars are only one ten-thousandth the candle-power of the sun, others ten thousand times as bright, when the effect of distance is taken into account. However, we might expect to find some sub-classes of stars, whose members are all of about the same brightness; in other words, we might hope to discover some earmark by which we can recognize the stars of very large candle-power—a thousand times that of the sun, say—and after checking such a "luminosity criterion" among the closer stars whose distances are measured by the parallax method, use it to determine the distances of other stars much farther away, by the brightness method. This is precisely the nature of one of the important research projects being undertaken at the Warner and Swasey Observatory by Dr. Nassau and Dr. Morgan of the Yerkes Observatory. They are using the B stars, which they can recognize by their spectra—or color—to determine distances to the far reaches of the Milky Way system. Previously, much the same method was applied by Dr. Shapley, first at Mt. Wilson, then at the Harvard Observatory, to the now-famous "Cepheid variables" whose period of fluctuation was found to be the earmark of their intrinsic luminosity. Shapley also found that certain types of clusters of stars have a total combined candle-power in each case some 30,000 times that of the sun. These "globular clusters," easily recognized by their form, are so powerful that they can be used to measure distances up to a million light years. Using the distances and directions of the globular clusters, Shapley plotted the positions of about one hundred of them and found that they are distributed in a large spherical volume of space, the center of this array being at a point in the brightest part of the Milky Way, in the direction of the

constellation Sagittarius. It was reasonable to assume, as Shapley did, that this point is the center of the Milky Way system.

At this juncture it is necessary to examine one of those refinements of method with which astronomers continually busy themselves. In using the brightness method of measuring distance, Shapley assumed that interstellar space is transparent; that the only reason one globular cluster appears fainter than another is because of its greater distance. For reasons too lengthy to indicate here, astronomers now know that dust and gas between the stars also dim the light of distant stars, and this smokiness of interstellar space, neglected by Shapley, made his distances some three times too large. Correcting for interstellar absorption, we find the distance to the center of the Milky Way system to be about 30,000 light years, a figure corroborated, incidentally, by studies of the dynamics of the galaxy—how it is held together without collapsing—and how it moves.

Our present picture of the Milky Way, then, is that of a flat pancake of stars, gas, and dust, some hundred million light years across, in which the sun and planets are located about two-thirds of the way from the center to the edge, and which is partly embedded in a spherical array of globular clusters extending out some 30,000 light years from the center. Now we can discuss what is beyond it.

Because they are extended surfaces, in contrast to the stars which appear as mere points of light in a telescope, the nebulae are some of the most interesting objects in the sky. From their form, their spectra, their positions, and, when established, their distances, two classes of nebulae can be distinguished; the galactic nebulae and the extragalactic nebulae. The former are, by and large, irregular in shape; they show the spectra (colors of light) emitted by low density gases, and, as their name implies, they are found mostly near the Milky Way in the sky, at distances which place them well within that system. The extragalactic nebulae, on the other hand, have circular, elliptical, and spiral shapes, their spectra are like a mixture of star spectra, they are found predominantly in parts of the sky other than the Milky Way, and their distances have been found to be enormously larger than anything in the galaxy. This last point is the crux of the matter; how can we prove that these spiral and elliptical nebulae are beyond the confines of the Milky Way system?

The answer is simple if you have a large enough telescope. With the large telescopes in existence today, it is possible to photograph the separate stars and clusters in the largest (and closest) of the spirals, the great Andromeda nebula. Using the brightness method, and taking account of the nearby smokiness of our own Milky Way system, but assuming that space outside is transparent, Hubble has shown that the Cepheid variables and clusters in the Andromeda nebula must be about a million light years away. Once the distances of another half dozen extragalactic nebulae were found by these methods, Hubble determined

their average intrinsic luminosity (about 85 million times the sun's), and can now determine the distances to much more distant nebulae with the aid of this information. Using longer and longer exposures on faster and faster photographic plates with larger and larger telescopes, Hubble has pushed the confines of observable space out to over a billion light years. In this vast volume he estimates there are some hundreds of millions of extragalactic nebulae, basing this estimate, of course, on a limited number of "sample" plates. Surveys now underway with the 20-inch refractor at the Lick Observatory and the 48-inch Schmidt camera at Palomar will cover somewhat smaller volumes more completely.

What can we find out about these distant objects so far beyond the Milky Way? It seems to me that the studies which have already been undertaken, and which are now underway, can be grouped in this manner, although there is some overlapping: first, we can find out more about *individual* extragalactic nebulae, their distances, sizes, masses, forms, and contents; secondly, as with any large class of objects, we can try to group them into further meaningful *sub-classes;* thirdly, we can study their *motions,* so far as they can be measured, and finally, their *numbers and distribution in space.* This last problem, literally the biggest in modern science, turns out to be linked with our fundamental notions of space and time.

Although it may seem simple, in principle, to determine the linear size of an object from its angular size and its distance, there are serious practical difficulties in the case of the nebulae. They have no clearly defined edges. Photographs of longer exposure show greater extensions, and there are reasons to believe that the Andromeda nebula, for example, is well over five times as large as what we can see in a telescope. The best photographs of this spiral show an angular extent corresponding to a diameter of about 40,000 light years, at its distance of over 700,000 light years. This is roughly the same size as the Milky Way system, which seems reasonable enough. (In fact, our picture of the Milky Way system has been developed partly by analogy to the form of spiral nebulae; in other words, it has long been in the back of astronomers' minds that the galaxy and the spirals are the same class of objects.) But other spirals and the elliptical nebulae are found to have diameters much smaller than this; from 2000 light years to 10,000 light years. We are thus forced to the conclusion that our galaxy is a giant among the spiral nebulae.

How can we "weigh" a nebula consisting of billions of stars? The method is similar to that for determining the mass of the sun; it depends upon measuring the motions of other masses in the vicinity. Since the outer stars in a nebula are attracted by the rest of the nebula, just as the planets are attracted by the sun, they would "fall" into the center were they not in motion in an orbit around that center. The motion is a measure of the gravitational pull of the nebula, which in

turn is a measure of its mass. We can scarcely hope to see—or photograph—such motion as a change of position in the sky; at a distance of a million light years a star would have to be moving at about 9000 miles per second across the line of sight to change its position by even one second of arc in a century! Luckily there is a more sensitive method of measuring motion along the line of sight (toward or away from us) by its effect on the spectrum. This "Doppler effect," which may be deduced from basic notions of the nature of light, space, and time, consists of a slight change in color, toward the red for recession, and toward the blue for approach, which can easily be detected with a spectrograph, if the light source has readily identified original colors in its spectrum. Early work at the Lowell Observatory, and more recent work at the Lick Observatory, has established from this effect that the spirals are rotating—at least, the ones viewed edge-on show more approach at one end than at the other. The amount of rotation of the outermost parts indicates a mass about one hundred billion times that of the sun for the Andromeda nebula, and smaller masses, about one billion to ten billion suns, for other nebulae. Similar reasoning leads us to expect that the Milky Way system is also rotating; this has been measured, and leads to a mass of over two hundred billion suns. Again we find our own galaxy larger than the rest, which seems to leave us in a "preferred" position in the universe. Moreover, there are other reasons to feel dissatisfied with these small measured values of nebular masses, as will become apparent later on.

The form and content of the extragalactic nebulae have contributed largely to their classification. Although there are others, the most meaningful classification seems to be one proposed by Hubble. He recognized three broad classes, based on form alone: the elliptical nebulae, the spirals, and the barred spirals. Within each of these classes there is a continuous sequence from "early" to "late" types—from smaller, more compact forms to larger, looser forms in the spirals, and from circular to more elliptical forms in the elliptical nebulae. The terms "early" and "late" seem to have been unhappily chosen, as it now appears that the "late" types, if anything, are younger in age. This conclusion is based by von Weizäcker (the German astrophysicist now at Chicago) on dynamical arguments, by Baade and others on the content. Baade, at Mt. Wilson, has superposed on Hubble's classification a distinction between two types of stellar population: Type I, associated with spiral arms, consists primarily of gas clouds and large, hot, blue stars which are thought, from other considerations (of stellar evolution) to be young; Type II population, associated with the elliptical nebulae and the cores of spirals, consists primarily of cooler stars, which may be quite as old as the earth and sun—a good three billion years. Hubble's three classes can be arranged in a kind of sequence, from the globular (circular appearing) elliptical nebulae, through the more and more elliptical types, through a hypothetical, missing type of spiral neither

normal nor barred, and then, in two parallel "branches" through the later and later types of spirals, both normal and barred. If the more recent ideas are correct, spiral evolution is taking place in the reverse direction; late-type spirals are collapsing to the final stage of globular nebulae.

One aspect of the content of extragalactic nebulae has received but scant attention until recently. Just as in our own galaxy, there is interstellar gas and dust in the other nebulae. The dust shows up as dark streaks on photographs; the gas emits light of the characteristic colors of hydrogen, oxygen, nitrogen, and other gases. In the extragalactic nebulae we have an excellent opportunity to study the distribution and physical conditions of these interstellar gases, and work now in progress at the McDonald Observatory is directed to this end.

We have already seen how one component of the motion (the radial velocity) of nebulae can be measured by the Doppler effect, and how their distances can be estimated by the brightness method. In 1925, Hubble and Humason at the Mt. Wilson Observatory noted a correlation between these two, in the sense that velocity of recession for nebulae on all sides of us increases with increasing distance. The later work of Hubble and Humason has shown a remarkable relation which holds as far as the spectra of nebulae can be observed: the velocity of recession on every side is proportional to the distance, and increases about 100 miles per second in each million light years.

At first sight, this observation seems to leave us—or our galaxy—in a central and highly repelling position, with all the rest of the universe "running away from us." A moment's reflection shows, however, that the "velocity-distance law" implies a symmetrical view from any other nebula; an observer there, considering himself "at rest," would see the others "running away" from him, and with velocities proportional to their distances. As for explanation of this strange behavior, there are several. The most easily visualized is based on the simple assumption that a cosmic explosion started the nebulae moving apart from a common starting point with speeds which have since remained roughly constant, and that the fastest moving ones have naturally got the farthest. From this simple concept, together with the rate of increase of recessional velocity with distance, we can readily compute that the explosion must have taken place some two billion years ago, a figure in fair agreement with the age of the earth determined from quite different data (radioactive decay in minerals). However, there are further complications which cast doubt on this simple explanation.

There are so many nebulae that a plot of each one's position in space would be literally an endless task. The best means of representing their distribution in space so far devised has been to count, or estimate, the numbers out to various distances. For instance, a survey by Shapley and Ames at Harvard showed over a thousand nebulae actually brighter than "thirteenth magnitude" (visible in a 6- or 7-inch tele-

scope), another by Mayall at the Lick Observatory shows an estimated nine million over the whole sky brighter than "nineteenth magnitude" (corrected for local obscuration) from sample plates taken with the 36-inch reflector, and two other sampling surveys by Hubble with the 100-inch telescope at the Mt. Wilson Observatory indicate that there are an estimated seventy million brighter than the "twentieth magnitude"—as faint as the 100-inch telescope can conveniently photograph. From the average intrinsic brightnesses of nebulae we can convert these figures to (roughly): 2000 within 13 million light years, 9,000,000 within 200 million light years, and 70,000,000 within 450 million light years.

These numbers are about what we would expect if the nebulae were *evenly* distributed, about two in each ten-billion-billion cubic light years. The numbers would then increase with the cube of the distance, since the volume of a sphere is proportional to the cube of its radius. The two deepest surveys, however, depart slightly from the cube law, indicating a thinning out of nebulae the farther we go from our galaxy. Now it has been repugnant to astronomers since the time of Copernicus to consider ourselves "at the center," as this thinning out would imply; hence a number of efforts have been made to interpret this last result, tentative though it may be, in such a way that no "center" is necessary. A number of difficulties arise; for instance, we are seeing the distant nebulae not where they are now, but where they were 13 to 450 million years ago, the time required for their light to reach us. Their intrinsic brightness, too, may not be constant in time. And it is certain that their light is so changed toward redder color by the Doppler effect that a correction must be made for its reduced power to blacken the photographic plate. What is more, a receding source should theoretically be fainter than the same source of light at rest.

Using the best data available in 1935, Hubble and Tolman concluded that these deepest surveys can be understood if space itself is "curved," somewhat like a two-dimensional surface can be curved into the form of a sphere. Just as there is not as much area in a circle on the surface of a sphere as there is within a circle of the same radius on a flat surface, so, too, there would be less "room" in "curved space" than in "flat space," as we normally conceive it, for spirals at great distances from us. This conclusion was inspired by Einstein's General Theory of Relativity, which ascribes a kind of curvature of space to what we normally call gravitation; in other words, space is expected to be curved by the mass of matter contained in it. Unfortunately the curvature of space necessary to explain Hubble's counts of the nebulae is very large — corresponding to a radius of only 500 million light years or so, which implies a very large amount of matter, not at all in agreement with the observed space density of spirals and the (small) masses measured from their rotations.

This is the impasse we have reached in our attempt to understand the

universe beyond the Milky Way. It may be removed by improving the observational data; by better measurement of the masses of spirals, including the faint outer parts, as we are trying to do at the McDonald Observatory; by finding evidence for matter between the spirals; by improving the correction for the Doppler effect as Stebbins and Whitford of Wisconsin are doing in their color work at Mt. Wilson; or by better and more complete surveys of the nebulae which are soon to be expected from the 48-inch Schmidt telescope and 200-inch telescope at Palomar. Or it may be removed by some new line of theoretical reasoning such as the Kinetmatical Relativity of Milne, in England, or by taking account of the clustering of nebulae, in a revision of Tolman's calculations, as now being undertaken by Omer at Chicago. Probably the solution will be found in some combination of these, but I have no doubt that, when it is reached, some even larger problem will be found to take its place.

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The Evolution of Fundamental Astronomical Concepts as Reflected in the Terminology of Astronomy

By EDGAR W. WOOLARD

From the etymological viewpoint, the technical terms of astronomy are of two kinds: (1) words artificially coined (usually from Greek or Latin) for an immediate occasion; and (2) words that gradually came spontaneously into use in a technical sense during the historical development of astronomy.

The latter are of especial interest, because usually they originated in an adaptation of ordinary words of everyday language to technical usage in senses more or less appropriate to their literal meanings; and these original literal meanings (with which many of them also continue to be used) reflect the mental processes that led to the formation of the technical concept. Incorporated in many of these terms is an implicit record of the origin and development of the ideas they denote, and a graphic portrayal of their meanings, often in a very vivid manner; but because the majority of these terms became established in ancient times, their significance and appropriateness frequently are obscured either by their derivation from ancient languages that are not now generally familiar, or by their remoteness from their origin—for in many cases, the form or usage has altered considerably during the centuries that have elapsed since the original introduction of the term.

Mere definitions of these terms, without any explanation of the basis for their introduction and usage, may therefore leave them somewhat enigmatical, or at best with no apparent reason why these particular

words should have been adopted to designate the concepts they denote. Formal etymologies alone are not very satisfying to the reader whose interest is not primarily philological,[1] but the historical source and origin of many of the terms, and the history of their usage, often help to make technical concepts less abstruse, and are instructive elements in the general history of astronomy. The linguistic expression of ideas by the terminology reflects the progressive evolution of concepts, and in it may often be traced the history of the development of astronomical thought. The terminology is an important aid in historical investigation, because similarity in the terms used by different peoples is an almost unfailing indication of mutual influence, and is a clue in tracing the origin and filiation of ideas.

The technical terminology now in use retains the impress of all the civilizations that successively contributed to the development of modern astronomy. Greek, Latin, Arabic, and traces of other languages are represented among present day astronomical terms in the various modern languages; and it is in the terminology that the imprint of the past in modern astronomy often is most immediately apparent. In many modern terms, an indication still survives of the original descriptive words or phrases in which the term had its source, expressive of the viewpoint and mode of thought in which the concept had its genesis.

This is especially true of the terms which relate to the phenomena that are most immediately apparent to direct observation, since these phenomena were the earliest to attract attention and to be systematically observed—the regularly recurring motion of the Sun, Moon, and stars across the seeming spherical surface of the sky from rising to setting; the unchanging configurations or constellations formed by the brighter stars; the motions of the Moon and the planets among the stars; the varying diurnal path of the Sun, the variation in the lengths of day and night, and the changing aspects of the constellations, regularly recurring in association with the cycle of the seasons; and the natural measures of time provided by the apparent motions. The technical terms used for the purpose of systematically describing the aspects of the heavens that depend upon these phenomena are among the most familiar and frequently employed astronomical words; they denote basic concepts formed in remote times, and most of these terms are of very ancient origin.

In some cases, an original word has survived from ancient times, practically unchanged in either form or meaning. An example is *horizon*, which is merely the ancient Greek word for this celestial circle, transcribed into Latin letters; it has persisted in many modern languages, unaltered except for slight variations in spelling and pronunciation peculiar to each tongue—*e.g.*, French *horizon*, German *Horizont*, Spanish *horizonte*, Italian *orizzonte*, and a similar word in Russian.

[1] *Cf.* Paul Friedlander, The Greek behind Latin, *Classical Journal*, **39**, 270-277, 1944.

This word is a very appropriate and highly descriptive designation, because the literal Greek meaning is *boundary*—it being understood that the boundary between the visible and the invisible parts of the celestial sphere is referred to. The word is the participle of the Greek verb that means to separate from, or to mark out by a boundary. As in the case of many terms, its technical usage originated through ellipsis of a descriptive phrase; in the earliest Greek writings on the celestial sphere, the idea of the horizon is expressed by the phrase "great circle which separates the visible from the invisible hemisphere," *i.e.*, which bounds the visible portion of the sphere; the habit then soon arises of referring simply to the "bounding circle in the sky," and eventually of using merely the participle alone, with "circle" understood. This participle appears as a single word, formally defined in its technical sense, in the astronomical writings of the geometer Euclid, although he also makes frequent use of the more complete phrases.

A large proportion of the technical terms that have been transmitted from ancient times had their source in Greek astronomy, but most of them have experienced more vicissitudes than "horizon." The ancient Greek astronomy was first introduced into western Europe by Latin translations of Arabic treatises, and later by translations directly from the Greek. The Arabic astronomy, after an initial impulse from the Hindus, had been based entirely on Greek astronomy, principally on Ptolemy; and the Moslem writers for the most part translated the Greek astronomical terms into the Arabic equivalents of their literal meanings. The Latin writers in some cases retained the original Greek word, in other cases literally translated the descriptive signification of the Greek term or its Arabic equivalent, and in some cases adopted or Latinized the Arabic word. Latin continued for a long period to be the language universally used for scientific writings in the West, and was not entirely abandoned until the early nineteenth century. Consequently, many of the technical terms used in Latin writings (whether Latin words, or Greek, or Arabic) survived in later writings in modern languages, though sometimes in more or less corrupted form, or with somewhat altered significance; some, however, were replaced in one or more of the modern languages either by literal equivalents in that language or else by words native to the language.

Among Greek terms which are still applied in the original sense but in Latin translation, is the word "equator": The Latin phrase *aequator dici*, an ellipsis for (*circulus*) *aequator dici et noctis*, "equalizer of day and night," was a free translation of the Greek phrase for this circle. In both languages the first word of the phrase came to be used alone.

The *point* on the equator where the Sun is located when days and nights are everywhere equal is now commonly denoted in English by the same word, "equinox," that is used for the *time* when the Sun crosses the equator, but in the ancient terminology the two were dis-

tinguished by separate terms; the word "equinox" is essentially the Latin *aequinoctium* (aequus + nox), which, like the Greek word of which it was the equivalent, denoted only the time at which the Sun was located on the equator—the point was explicity designated *punctum aequinoctialis*. Essentially the Latin word for the equinox has also been retained in French and Italian; but in the German language it has been replaced by the literal equivalent *Nachtgleiche*, and similarly in Russian.

Occasionally, Hindu words are found in the Latin writings, having been introduced from the Arabic—*e.g.*, *aux*, a medieval Latin term for the longitude of the apogee—but they have not generally been retained.

The words in terms that were successively adopted from one language into another without translation often became more or less modified or corrupted in form, and some are now represented by words that differ considerably from the originals. This is particularly true of terms that originated in transliterating Arabic expressions and their colloquial forms into other languages. *E.g.*, "azimuth" and "zenith" both are derived from the Arabic word *samt* meaning "way" or "direction": "Zenith" represents an ellipsis of the phrase *samt al-ra's*, "the direction of the head" (the same designation that was used by the Greeks), in which, by a common scribal error of *ni* for *m*, *samt* became *cenit* (among other forms) in many early Spanish versions of Arabic writings; from the Spanish and Medieval Latin, this transcription and its variants were adopted into Old French and Middle English. It still remains *cenit* in Spanish; but by the 16th century, the form "zenith" had evolved in English. Similarly, "azimuth" is from *al-samt* (plural, *al-sumūt*), an ellipsis of the Arabic phrase for "the direction [in degrees, from the east or west point] in the circle of the horizon"; the transcription "azimuth" corresponds to the Arabic pronunciation *as-samt*, in which the consonant of the prefixed definite article is assimilated to the sibilant with which the word begins. In genitive constructions, such as the one from which "zenith" is derived, the article is omitted before the first word. The term "nadir" is essentially the Arabic word for "opposite"; in its present usage, it is an ellipsis of "the opposite of the zenith," but formerly it was also used with the now obsolete meaning of the point in the heavens diametrically opposite any given point, especially opposite the Sun.

Corruptions of Arabic expressions are especially common in star names; in ancient astronomy, the brighter stars were commonly identified by describing their positions in the constellation figures, and the phrases used for this purpose by the Moslems are the source of many of the proper names now in use. *E.g.*, "Denebola" represents *dhanab al-asad*, "the tail of the Lion"; this star is designated in the Greek and the Arabic star catalogues as "the star at the end of the tail."

"Aldebaran" is from the Arabic designation *al-dabarān*, "the follower" [of the Pleiades].[2]

The familiar terms "right ascension" and "declination" are of particular interest as examples of terms which during transmission from ancient times have come to be used with a significance somewhat different from the original one, but which have persisted essentially unchanged in verbal form and hence retain the impress of former modes of thought. These terms have been discussed at length in a previous paper by the writer.[3] Although they denoted the same geometrical quantities in ancient times that they now denote, both were originally restricted to the ecliptic and were defined from a different point of view; the terminology expresses the original viewpoint, and therefore the reason for the names is not apparent from the modern definitions.

In the case of some terms, the changes in usage that have occurred have been so great that the word now has an entirely different meaning. An interesting example is "climate," which in ancient technical usage was an equivalent of terrestrial latitude; it referred to the length of the longest day, as determined by the inclination of the rays of the Sun, but was gradually extended to the whole complex of the associated average meteorological conditions until eventually it lost its original significance entirely.

On the other hand, some terms have continued to be retained in practically their original usage although they have long since ceased to be literally appropriate, and are now only conventional designations —*e.g.*, the classification of the planets into "superior" and "inferior," *i.e.*, higher and lower than the sphere of the Sun, is a vestige of the former geocentric cosmologies that is no longer literally applicable. However, some of the terminology of the ancient planetary theories was transferable in a natural way to the modern theory, and its retention was entirely logical. "Eccentricity," *e.g.*, has essentially the same significance for the Keplerian ellipse as it had for the Ptolemaic eccentric circle.

Most of the geometric terminology of the conic sections is from Apollonius; but "focus," literally "hearth" or "fireplace," was introduced in its technical sense by Kepler, presumably because of the significance of the focal points in optical theory. Many other astronomical terms have likewise been established in comparatively recent times—an interesting example is "Saros," which, though it is a Babylonian word, was introduced in its present astronomical usage by Halley in 1691.[4] On the other hand, from time to time throughout the history of astronomy, terms once established have dropped out of use, either

[2] For numerous other examples, see George A. Davis, Jr., The Pronunciations, Derivations, and Meanings of a Selected List of Star Names, POPULAR ASTRONOMY, **52**, 8-30, 1944.

[3] Edgar W. Woolard, The Historical Development of Celestial Coordinate Systems, *Publ. Astr. Soc. Pac.*, **54**, 77-90, 1942.

[4] O. Neugebauer, *Quellen u. Stud. z. Gesch. Math. Astr. u. Phys.*, Abt. B., Bd. 4, pp. 407-410, 1938.

because no longer needed or else because supplanted by essentially different ones. For example, in late Roman times, the Latin transcription *ecliptica* of the Greek word for "pertaining to an eclipse" replaced the Greek phrases "great circle through the middle of the signs [of the zodiac]" and "oblique circle" (*sc.* to the equator) by which the ecliptic had previously been designated and which reflect the nature of the earliest concepts of this celestial circle.

Vestiges of the picturesque terms *caput draconis* and *cauda draconis* formerly often used for the lunar nodes still survive in the "draconic period" of the Moon, and in the symbols commonly used for the ascending and descending nodes. Traces of former mythological fancies and legendary associations also remain in other astronomical symbols and ideograms: The planetary symbols contain elements that date back to ancient Babylonia;[5] and the symbol denoting the Sun is an Egyptian hieroglyph for the Sun.

The borrowing of common words for use in denoting scientific concepts has continued into modern times, along with the introduction of coined words for needed new terms. The extent to which either an ancient or a modern term is used essentially unchanged in different modern languages appears to be related to the language from which it originated either historically or etymologically;[6] but practices are not uniform in different languages. For example in English, the word "longitude" is the Latin *longitudo*, a translation of the Greek term literally meaning length; while in German, *Länge* is used, the German word for length. Likewise, for geographical latitude, *Breite* is used in German in place of the Latin translation *latitudo* of the original Greek; but for astronomical latitude, the descriptive term *Polhöhe* is employed, while English does not have a separate term.

Similar diverse practices are followed in the names of the cardinal geographical directions. The cardinal reference points of the horizon were suggested by the phenomena of the diurnal motion; as shown by the ancient terminology, they were originally conceived as the directions toward the point of sunrise, toward the highest point in the sky or midpoint of the diurnal motion, and so on. The ancient Greek words for "east" and "west" were derived from the verbs meaning to rise and to sink, and the same words were used to signify, among other things, the rising and setting of the Sun. The Latin translations were *oriens* and *occidens*. As designations for directions, these terms have been replaced in modern English by the words "east" and "west" of Anglo-Saxon origin (which likewise embody root ideas of dawn and evening); but the usage of the Latin terms to denote also the lands that lay in those directions from the Greco-Roman civilization has been

[5] A. S. D. Maunder and E. W. Maunder, The Origin of the Planetary Symbols, *Jour. Brit. Astron. Assoc.*, **30**, 219-223, 1920.

[6] See Parry Moon and Domina Eberle Spencer, Internationality in the Names of Scientific Concepts, *Amer. Jour. Physics*, **14**, 285-293, 1946.

retained in the appellations Orient and Occident commonly applied to the eastern and western countries of the Earth. In German, however, *Morgenland* and *Abendland* are used instead of these Latin terms.

U. S. Naval Observatory, Washington, D. C.

Mt. Wilson and Palomar Observatories Receive Award

On November 8, at the Rochester Club, Rochester, New York, the 1949 U. S. Camera Achievement Awards for outstanding contributions to photography were presented. The 1949 Achievement Awards were made to three organizations and one individual, representing four classifications of photographic endeavor. The recipients were:

Mt. Wilson and Palomar Observatories

Armour Research Foundation

Polaroid Corporation

Edward Steichen, Director of the Department of Photography, The Museum of Modern Art, New York City.

Following are the citation used in making the Mt. Wilson and Palomar Observatories award, and the acceptance speech by Dr. Walter Baade, which may be taken as an authoritative statement concerning the status of the 200-inch at that time.

"Without a doubt the still pictures of the year with the most significance were the experimental photographs recorded with the giant 200-inch Hale Telescope of the Mt. Wilson and Palomar Observatories. In actuality the telescope is the world's largest camera. But it is dwarfed by its subject—the universe which it explores.

"Yet it is on this tiny window that man pins his hopes of solving many of the baffling mysteries of space. And there is reason to believe that the findings yielded by the photographic observations will benefit all mankind. Already, the test photographs have revealed that celestial bodies exist at the extreme power limit of the telescope.

"Mysteries of the nature of whether canals exist on Mars may well be relegated to non-mysteries when the 200-inch mirror focusses its image on a photographic plate. Facts, *i.e.*, possibility, concerning space travel might well be established through the future observations of the Hale Telescope. Overall, photography as it is employed by the Observatory is the tool with which man will solve many of the age-old problems of the universe.

"It is for this pioneering experiment in space beyond that previously explored by man that Mt. Wilson and Palomar Observatories receive the U. S. Camera Achievement Award."

ACCEPTANCE SPEECH OF DR. WALTER BAADE

The Mount Wilson and Palomar Observatories, which I have the honor to represent here tonight, greatly appreciate this U. S. Camera Achievement Award.

In one respect the award must be quite unique, because it recognizes the performance of an instrument which has not yet demonstrated its full power. You probably know that the first sky tests of the big mirror in the beginning of this year revealed a slightly turned-up edge. This outer zone, some four millionths of an inch high, has been successfully rubbed down during the past five months. Last week the optical surface of the mirror was aluminized, and by the middle of this month actual research work with the 200-inch Hale Telescope will be under way, although tests and minor adjustments of the mirror may continue for the next two years. Thus after many years of planning, building, and final testing, the Palomar giant is ready for work.

I have been asked to tell you in a few words what we expect to do with the 200-inch. The answer is: we shall continue where we had to leave off with the 100-inch telescope. Though relegated now to second rank, the 100-inch telescope has been a most successful instrument. Two great discoveries made with it will always remain landmarks in the human conquest of space and time. The first, that the mysterious spiral nebulae, the nature of which had been debated for over one hundred years, are actually vast stellar systems like our own galaxy and are strewn throughout the depths of the universe up to distances whose only limits are set by the failing powers of our instruments (500 million light years for the 100-inch). And the second, that this vast universe of galaxies is not in a stationary state, but expanding.

We know now that two of the observational data just mentioned—the density distribution of matter throughout space as we go to larger and larger distances, and the corresponding increase of the so-called red shifts which measure the expansion—are the clues to the type of universe we are inhabiting: whether it is an infinite universe or an unbelievably large, but nevertheless closed and finite universe. Attempts to settle these questions with the data provided by the 100-inch telescope have remained inconclusive. With the 200-inch telescope we shall reach twice as deep into space, to about a billion light years, and to red shifts which amount to one-fourth of the velocity of light. There is every reason to expect that at these large distances the distinguishing features between the different types of possible universes become so pronounced that the final decision can be made without bias.

The second problem which will play a big role in future researches with the 200-inch telescope is a spectrographic one, and it concerns the relative abundance of the chemical elements in stars of all sorts. Qualitatively it has been known for a long time that whatever objects in the universe we investigate with our spectroscopes we find them composed of the same chemical elements with which we are acquainted

here on our earth. But in recent years it has become possible not only to state that there is, for instance, hydrogen and iron and titanium in a certain star, but to determine accurately what is the percentage contribution of helium, iron, titanium, etc., to the total mass of the star—in other words, to perform a quantitative chemical analysis of a star. Such investigations require spectrographs of very large dispersion, and hence large telescopes to feed the necessary light into the spectrograph.

Investigations of this kind have become particularly interesting in recent years, because we know now that the sun, and probably the majority of the stars, maintain their radiation by a nuclear chain reaction in which hydrogen is converted into helium. Hence in the course of time the hydrogen content of a star will decrease, whereas the helium content will rise steadily, so that the ratio of helium to hydrogen would be an indicator of the age of a star. Now the sun and the majority of the stars which are fueled by the hydrogen-helium process are so economical in spending their energy that they have consumed at best a very few per cent of their hydrogen content since they were formed. Things are quite different with another group of stars, the real big fellows which radiate away their energy at such a prodigious rate that their lifetimes must be very short—from ten to a hundred million years, whatever source of atomic energy they may tap. Either they live on the hydrogen-helium process too, then, because their lifetime is short, we should find among them quite a number which are near the end of their hydrogen supply. Or they know a better trick. In either case, a check of their chemical composition should reveal what they are up to, and where to look for the explanation.

Long before the physicists had begun splitting atoms it had become obvious that our sun, in order to maintain its radiation, was tapping in some way or other the forces hidden in the atomic nucleus. We know now that the sun and the stars are vast atomic power plants utilizing nuclear reactions which probably never can be realized in our terrestrial laboratories. In a very real sense the stars have thus become the cosmical laboratories of the nuclear physicist. We have no doubt that the 200-inch Hale Telescope will prove a powerful tool in these explorations.

Weather Prediction from Clouds and Winds

The accompanying illustration shows a simple new instrument designed to predict local weather conditions accurately for a 24-hour period on the basis of prevailing clouds and wind. The weather guide, small enough to fit in a pocket, was developed by Dr. Irving P. Krick president of the American Institute of Aerological Research. He built

into the device the most recent war-born forecasting techniques and the data gained from 50 years of daily weather charts for the entire Northern Hemisphere. These data have brought out the fundamental relationships between coming weather and each combination of cloud and wind direction, resulting in the forecasts appearing on the instrument. Because it is so simple to operate and in a convenient size, the weather guide is bound to find wide popular favor, Dr. Krick believes. In addition, dependable weather information is necessary in practically every activity, either profession or hobby, he feels.

To predict the weather for the next 12 to 24 hours with the new device, the first step is to note wind direction. Then the clouds in the sky are matched with one of seven colored pictures of cloud formations on the face of the instrument. A simple turn of a dial aligns a red arrow with the wind direction and the correct weather prediction appears in a little window. Forecasts based on wind direction and cloud formations are much more accurate than those prepared from a barometer which considers only air pressure, Dr. Krick states. Weather is caused by certain moisture and temperature conditions in the atmosphere, and air pressure alone cannot reveal these complexities.

Because clouds and wind are the "signs in the sky" offering clues to coming weather, Dr. Krick claims that the weather guide can forecast with high accuracy. The instrument is new, he adds, but its fundamental principle is as old as weather itself.

Dr. Krick has been active head of the Meteorology Department of the California Institute of Technology for the past 15 years. During World War II he served as Deputy Director of Weather Services and Chief of the Weather Information Section, U. S. Strategic Air Forces in the European Theatre, responsible to General Eisenhower for operational weather advices.

The weather guide, here described, is produced by the American Optical Company, Southbridge, Massachusetts.

The Relation between the Latitude of a Place and the Declination and Meridional Zenith-Distance of a Star

By FREDERICK C. LEONARD

The well-known relation

$$\phi = \delta + z_m, \tag{1}$$

in which ϕ denotes the astronomical latitude of a place, and δ and z_m respectively the declination and meridional zenith-distance of a star,[1] is universally true, regardless of whether the place is in the northern or the southern hemisphere and the star is above or below the horizon, provided the following two rules are observed:

(1) δ is measured *positively northward from the apex of the equator*,[2] and may take any value between and including $-180°$ and $+180°$, being reckoned over the pole for stars at lower culmination.

(2) z_m is measured *positively southward from the zenith*, and may take any value between and including $-180°$ and $+180°$.[3]

The expression for latitude in Talcott's zenith-telescope method, namely,

$$\phi = \tfrac{1}{2}(\delta_s + \delta_n) + \tfrac{1}{2}(z_s - z_n), \tag{2}$$

in which δ_s, δ_n, and z_s, z_n respectively represent the declinations and meridional zenith-distances of two stars, one that culminates south of the zenith and the other north of it, results obviously from the application of the fundamental equation (1) to the cases of two such stars, the zenith-distance of the northern star (z_n), in accordance with rule (2), being negative.

Equation (1) and the two simple rules that go with it evidently supersede all those confusing formulas and precepts generally encountered in the treatment of this subject.

Department of Astronomy, University of California, Los Angeles

[1] The term *star* is used thruout this note in the sense of any celestial object.
[2] *I.e.*, its intersection with the upper branch of the meridian.
[3] In practice, z_m never, of course, numerically exceeds 90°.

Another Unusual Meteor

By H. H. NININGER

ABSTRACT

A record of observations made by the author on what seems to have been a spiraling meteorite as indicated by the indirect course of the observed meteor. Its color was also unusual, which may or may not be significant.

Last night, Friday, July 8, 1949, in the Lake Mead camp ground, I spread a blanket on top of my car and stretched out on my back to watch the sky while enjoying a respite from the afternoon heat until it became cool enough to sleep. About 9:30 P.M., M.S.T., a meteor appeared approximately three degrees to the northeast from the zenith and moved in an easterly course, very slowly as viewed from my position, so slowly, in fact, that in about three seconds it covered only about nine degrees of arc.

My impression is that on first appearance it was of normal color; but that it reddened rapidly. I am very sure that in its later course it became the deepest orange-red color of all the meteors I have witnessed.

When it first claimed my attention (and I had been looking directly at that portion of the sky) it was of about second magnitude. It rapidly increased in size so that by the time it had covered two-thirds of its course, it had attained a brilliance at least double that of Jupiter which was shining brightly in the clear southeastern sky. Then it flashed into

SKETCH OF UNUSUAL METEOR SEEN BY H. H. NININGER ON JULY 8, 1949

that dazzling, explosive brilliance which one sees in very bright meteors at, or near, their finish and which has been recorded in some rare photographs as spindles of intense light; only this one, instead of appearing the usual bluish white, was an intense orange color. Along the axis of the spindle I seemed to see a lightning-like streak of whitish light mingled with the orange. Beyond this spindle, the meteor continued for about one degree, but only about equaling Jupiter in brightness. Then it faded without any further explosion. No persistent luminous train or cloud was seen.

Abundant sparks (red) were given off throughout the middle third of the meteor's course. If these continued through the explosive flash I failed to notice them; but the brilliance was such that sparks may

have been masked by the intensity of the flash which lighted up a considerable portion of the sky.

The most unusual feature of this meteor was its apparent deviation from a direct course which I interpret as a spiraling motion because of its very rhythmic nature. During its passage there were four complete oscillations which, if my interpretation is correct, represented as many spiral revolutions. Then after the flash its course seemed straight but inclined slightly toward the vertical from the previous line of travel.

I have several times on previous occasions noticed what I believed was indirect meteor flight but never could I be quite sure before because never before could I completely eliminate to my own satisfaction the several possible sources of error. But in this case, the evidence seems entirely conclusive. Seeing conditions were ideal. There was no unsteadiness of the atmosphere as checked by naked-eye observation of the stars. I lay on my blanket atop the 1942 Chevrolet very comfortably for more than an hour, from 9 o'clock until after 10:15. There were no disturbances of any kind and at no time during the period was there any unsteadiness of vision. Three sporadic meteors had appeared previous to the one here described. All were normal straight coursed objects. Two were small and one was slightly brighter than first magnitude and covered about 22 degrees of arc. Three more appeared afterward. They, too, were normal except that one, of about the brightness of Jupiter, showed much the same red color as did the one under discussion; but it was rapid and straight coursed. It seemed to arise in the same radiant as the spiraling one but its trajectory was toward the west-southwest. It left no sparks and covered about 20 to 25 degrees of arc.

The indirectness of my special meteor seemed perfectly rythmical. It impressed me from the first when I thought its brightness was not going to be unusual. There was time actually to concentrate on the problem of this rythmic movement which I have often wished to verify. However, during the whole evening until this meteor appeared, the subject of "wobbling or spiraling" meteors had not occurred to me. Indeed, I cannot remember that it has come into my thinking for some months.

My impression is that the meteor was traveling in a nearly vertical course; that its apparently slow movement was due to foreshortening; that for an observer 100 miles to the south or the same distance to the north it would have covered probably 30 degrees of arc. Observers farther west might have seen a much longer course, too. Settlements are scarce in these parts but we hope that some other parties may be able to report on it.

My time is probably not accurate, as I relied upon a neighboring camper who was not certain of his time. I had not planned to make any recorded observations but was merely skywatching for pleasure. However, any meteor is a signal for immediate action on my part.

I trust this observation may serve some useful purpose.

American Meteorite Museum, P. O. Box 1171, Winslow, Arizona.

Some Solar and Related Meteorological Periods

By H. W. CLOUGH

The internal constitution of the sun, notwithstanding its gaseous nature, is unsymmetrical with reference to the plane of its equator. The two hemispheres differ widely in their eruptive activities. For months, one hemisphere may be active while the other remains relatively quiescent. Furthermore, there seems to be a tendency to an alternation of activity over short periods of time, as a month. There is little or no correlation between their respective monthly variations. During the years 1938-1947, the mean monthly spotted areas, when correlated by the variate-difference method, gave a coefficient around zero. If the long-period variations, which affect both hemispheres together, were eliminated, the coefficient would be negative.

The 30-month period. In 1924[1] I called attention to a period with an average length of about 30 months in the mean monthly latitude of the entire spotted area, which shifts systematically from one hemisphere to the other. This value is computed by forming products of each hemisphere's monthly spotted area by its mean latitude and dividing the difference of these products by the total area. The quotient is given the plus or minus sign according as the greater product is that of the northern or of the southern hemisphere.

The monthly ratios of the northern to the total spottedness supply additional data showing variations substantially in accord with those of the mean latitude.[2] Using data from various observatories since 1855, the length of this period has averaged 31 months, ranging between 1.75 and 4.0 years. The fluctuation is satisfactorily shown in a plot of two six-month means per year, one centered April 1, and one centered October 1.

When the 11-year variation is eliminated from the smoothed monthly relative numbers, a secondary fluctuation appears, as I stated in 1924.[1] From 1750 to 1924 the length of this period averaged 28 months, but for the past 60 years has averaged 30 to 31 months. There is some uncertainty, however, in the determination of a precise date for a maximum or minimum phase.

There are long-period variations in the length of the period as derived from the percentages of northern spottedness. Long intervals between like phases occurred around 1860, 1895, and 1930, while short intervals occurred around 1875, 1910, and 1945. This long period of about 37 years corresponds with the length of the Brückner meteorological cycle. Short intervals of the 30-month solar cycle occur near the Brückner epochs of low temperature and excessive rainfall, while long solar intervals coincide with epochs of extreme warmth and dryness.

An 11-year variation of small amplitude is disclosed when the yearly data are smoothed by a 5-term formula. The maximum percentages of northern spottedness occur about 3 years before the 11-year epochs of maxima.

Comparison of the solar data with the temperature at St. Louis since 1875 shows that 30-month epochs of maximum or minimum percentages of northern spottedness precede epochs of minimum or maximum temperature, respectively. The time-lag varies in length, but averages around 1.25 years.

The following table gives epochs of maximum and minimum percentages of northern spottedness, in continuation of the series published in 1928.[2]

Maximum	Minimum
1922.00	1923.25
1924.75	1927.75
1928.75	1930.00
1931.25	1932.50
1933.25	1935.25
1937.50	1938.50
1939.25	1940.00
1941.75	1942.50
1943.50	1945.25
1946.50	1947.25
1949.00	

The 9-month period. When the monthly mean latitudes or the ratios of the northern to the total spotted areas are smoothed by an appropriate formula as $(a + 2b + 2c + d)/6$, a short period of about 9 months is disclosed. In 1936[3] I stated that this period could be traced in the Greenwich solar data since 1873. A graph showed the variation from 1914 to 1935, together with curves of certain meteorological data with which the solar data are correlated.

Supplementing the Greenwich data with data from the Lyon Observatory, 1889-1934, the Ebro Observatory, and the U. S. Naval Observatory from 1927, the length of the period for the past 75 years has averaged 8.8 months. However, the length of the period varies between a minimum of 5 months and a maximum of 13 months. These extreme values are partly due to uncertainty, at times, in the determination of a precise date for a phase. The frequency distribution of these varying intervals between like phases is decidedly unsymmetrical, since the most frequent interval is 8 months. An analogous range of variation is shown by the 11-year sunspot period, which varies between 7 and 16 years, with an average length of 11.1 years.

The variations in the length of this period are not fortuitous, but are definitely related to the occurrence of phases of longer periods. Superposed upon these variations in the phase-intervals are longer variations. There appears to be a period of about 30 months which is related to the 30-month period in the percentages of northern spottedness. Long 9-month intervals tend to occur near maximum values of the percentages and short intervals, 15 months later, near minimum

values. An 11-year period is also prominent, with long 9-month intervals near sunspot minima and short intervals near maxima. The master cycle[4] of 80 to 85 years is also shown by the occurrence of very short intervals averaging 7 months, in the 1870's and the 1940's, concurrent with the excessive activity of 1870 and 1947; while long intervals, averaging 11 months, occurred near the minima before and after 1906, the quietest maximum since 1816.

These 9-month variations in the hemispherical shifts of solar spottedness are closely correlated with meteorological variations. It is found that an excess of spots in the northern or southern hemisphere is followed by relatively low or high temperature, respectively, in the Plains regions of western Canada and the northwestern United States. The lag varies in length but averages six months.

The 3.5-month period. By contrast with the 30-month and 9-month periods, which are well shown by using data from separate hemispheres but less clearly by the total spottedness, a period of shorter length is evident from a study of the daily relative numbers since 1870. The 27-day period, due to solar rotation, which is at times prominent, is satisfactorily eliminated by computing a 30-day mean from the fifteenth of one month to the fifteenth of the following month, to be plotted with the usual monthly mean. With the daily relative numbers smoothed in this manner, a period is disclosed, averaging 3.5 months in length. Like all solar periods, this period is variable, ranging in length from 2 to 5 months, and with amplitude varying directly with the length of the period. However, these wide variations are not fortuitous in their sequence, but exist in groups of long and short intervals separated by about 15 months. These 30-month epochs of long and short intervals nearly coincide with similar epochs of the 9-month period.

The following table gives 30-month epochs of long intervals of the 3.5-month period. The epochs of short intervals occur approximately midway between the epochs of long intervals. These long-interval epochs average 0.4 year earlier than the 30-month epochs of maximum percentages of northern spotted areas.

LONG INTERVALS

1872.0	1894.5	1921.5
1873.7	1897.2	1924.5
1875.5	1900.5	1927.2
1877.5	1903.0	1930.0
1880.0	1905.7	1933.0
1882.0	1908.5	1936.0
1884.7	1911.0	1938.2
1887.2	1913.7	1940.5
1889.5	1916.0	1943.5
1891.7	1918.2	1945.7
		1948.0

It is to be borne in mind that only one-half of the sun's surface is visible at any one time. Since the spots are the only available indication of solar activity, the daily measurements supply only one-half of the

total external evidence of activity. As a result, there should be expected more or less irregularity in short solar periods, especially around epochs of minima.

Comparison of these 30-month epochs with similar epochs of total spottedness shows that the intensity of solar activity varies inversely with the length of the short periods. This rule applies to all solar periods and is well illustrated by the 11-year epochs. Unusually high maximum epochs follow very short intervals from the preceding minimum.

A correlation of the 3.5-month variation with meteorological variations results from a study of monthly pressures since 1910 in the coastal regions of Alaska and British Columbia. It appears that the 3.5-month epochs of maximum solar activity generally precede epochs of high pressure in these regions.

Some long solar periods. From an analysis[4,6] of the intervals between epochs of maxima since 301 A.D., several long periods are disclosed, with lengths 37, 83, 300, and 1400 years. The following table gives the 11-year epochs of maxima since 301 A.D. Interpolated epochs are designated by an asterisk. The next maximum epoch is due about 1960.

EPOCHS OF SUNSPOT MAXIMA (FRITZ EPOCHS REVISED), 301-1603; AND WOLFER, 1615-1947

301	577	848	1130	1401	1685
311	585	859	1138	1413*	1693
323	595	870	1148	1424*	1705
332*	603	879	1161	1435	1718
342	616	890	1177	1449*	1727
354	629	906	1185	1462	1738
361	643*	918	1193	1472	1750
374	654	928	1204	1483	1761
388	665*	940	1214*	1497	1769
397	676	948*	1225	1511	1778
408	686*	957	1238	1518	1788
421	698*	970	1247	1529	1804
434	710	979	1260	1538	1816
443*	718*	993	1270	1548	1829
453	727	1003	1278	1560	1837
466*	742	1013	1291	1572	1848
479	754	1026*	1300*	1580	1860
488	765	1039	1308	1591	1870
501	776	1048*	1324	1603	1883
512	787	1057	1334	1615	1894
522*	797*	1069	1348	1626	1906
531*	806	1081	1360	1639	1917
540	816*	1096	1372	1649	1928
555	827	1104	1380	1660	1937
566	840	1117	1388	1675	1947

Figure 1 is a diagram constructed to show the general accuracy of the 11-year epochs. The epochs are plotted in rows 300 years long. Each epoch is joined to the 27th epoch preceding and following. A vertical trend of the connecting lines corresponds to a period-length of 11.11 years. The normal length during the past 1600 years has been 11.07 years.

Figure 2 is a graphical periodicity tabulation designed to show clearly the 37-year period. The intervals between 11-year epochs of maxima are tabulated in 37 columns and with rows averaging 300 years in length. The date of the zero column is at the left. Maximum intervals averaging 37 years apart are underscored and joined to the eighth interval preceding and following. A vertical trend of the connecting lines corresponds to a mean length of 37.4 years. The varying dis-

FIGURE 1

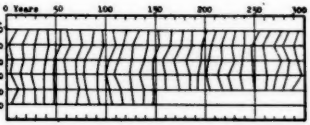


FIGURE 2

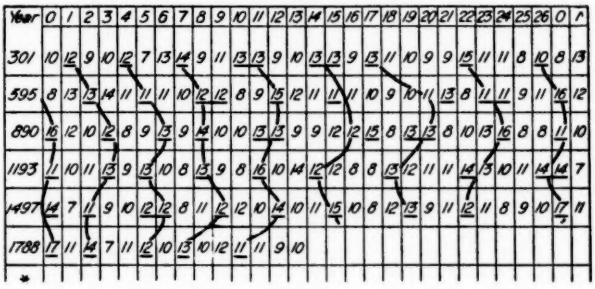
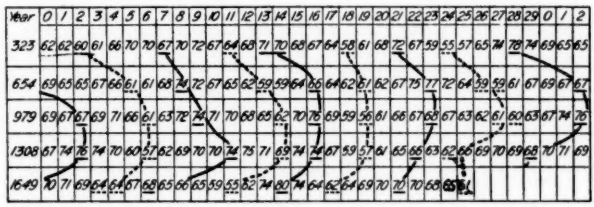


FIGURE 3



tances apart of the curves illustrate the 300-year variation in the length of the period, which ranges between 25 and 50 years.

Figure 3 is designed to show the 83-year period in the length of the 11-year period. The intervals between maxima are summed by the formula $(a + 2b + 2c + d)$, and are tabulated in 30 columns, each 11.1 years long, and with rows averaging 332 years in length. The date of the middle of the zero column is at the left of the tabulation. Maximum and minimum epochs of the 83-year period are indicated by appropriate underscoring, full line for the maxima and dotted line for the minima. Each epoch is joined to the fourth similar epoch preceding and following, and the varying distances apart and long-period curvatures of the resulting curves illustrate the 300-year and 1400-year variations in the length of the period, which ranges between 65 and 95 years.

Long meteorological periods. Study[6,7] of meteorological data has disclosed long periods corresponding to the long solar periods. A 37-year period has been known since 1890 as the Brückner meteorological cycle, with lengths ranging between 25 and 50 years. The epochs of this cycle are closely correlated with the 37-year solar epochs.

A study[4] of ancient records of the occurrence of auroras, severe winters, and other phenomena for 2000 years, and of tree-ring data for 3000 years has revealed the 83-year and 300-year periods in their variations.

Origin of solar periods. There are two theories to account for the origin of the solar periods. Some have postulated an external origin for the 11-year variation. While minor effects may be due to planetary action,[5] the internal origin of the variation is evident from the wide and systematic changes in latitude of the spots and prominences during each cycle.

The internal origin of the short periods seems evident from their interdependence, as shown by the 30-month, 11-year, and 37-year periods which appear in their variations. Likewise, the long periods are not independent of each other. The variations of each period are governed by the periods of greater length.

Although the solar periods are of variable lengths, their variations are systematic and orderly, and therein lies the possibility of their prediction and that of the meteorological phenomena which are correlated with the solar phenomena.

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The Planets in January, 1950

By RAYMOND H. WILSON, JR.

Note: The time employed is Central Standard Time unless otherwise indicated. The phenomena have been chosen and described for the North American continent, and especially for the United States. The basic data have been taken principally from the *American Ephemeris and Nautical Almanac.*

Sun. The sun will have started north again and by the end of the month will be about 17 degrees south of the equator. The earth will be at perihelion, that is, nearest to the sun, on January 3.

Moon. The phases of the moon will occur as follows:

Full Moon	January 4	2 A.M.
Last Quarter	11	5 A.M.
New Moon	18	2 A.M.
First Quarter	25	11 P.M.

The moon will be at perigee, that is, nearest to the earth, on January 13. A daytime occultation of Spica will be generally visible, with the help of a small glass, on January 11 at 8:50 A.M. The far West will not see this occultation, but will have a more favorable view of an occultation of the Pleiades on January 28 beginning at about 10 P.M.

Evening and Morning Stars. Jupiter and Venus will shine brightly in the early evening sky for the first part of the month only; Saturn will rise just before, and Mars shortly after midnight.

Mercury. Mercury will stand at a maximum eastern elongation of 19 degrees on New Year's Day. Hence it might be glimpsed in the southwest twilight on the first few days of the month.

Venus. This planet will be the most prominent object in the early evening sky at the beginning of the month. However, by the last week it will have approached so close to the sun as to be invisible, and on the last day will be in conjunction with the sun, thus passing into the morning sky.

Mars. The eastward movement of Mars toward Spica will be slowed during this month, but its brightness will rapidly increase to a magnitude greater than that of Saturn, which now trails along some 15 degrees to the west.

Jupiter. The sun will overtake and hide Jupiter sometime about the middle of the month. Venus, the brighter of the pair, will be retrograding to the west toward Jupiter, but their conjunction on the 25th will be invisible in the bright twilight without optical aid.

Saturn. By the end of the month Saturn will be rising by 10 P.M., and this interesting object will again be available to evening observers. In the late evening of January 8 the waning moon will be passing only a few minutes south of the planet.

Uranus. Uranus will be moving west-northwestward at about 2 degrees northwest of η Geminorum.

Neptune. Neptune will be almost stationary at a point less than 15 minutes of arc southwest of θ Virginis.

Department of Mathematics, Temple University, Philadelphia, Pa.,
November 1, 1949.

Asteroid Notes

By HUGH S. RICE

The annual volume of asteroid positions (*Minor Planets for 1950*) is now published, and contains over 1200 ephemerides of these planets as they come to opposition. The volume is published by the Cincinnati Observatory under rules set up by the International Astronomical Union. The calculation of so many

planets—a large undertaking—is done as a co-operative undertaking by several observatories. For example, the 1950 ephemerides were computed as follows: 485 of them issued from the Leningrad asteroid headquarters, and 468 from the Astronomisches Rechen-Institut at Heidelberg; a lesser number (in descending order) were done at each of these centers, Tokyo, Madrid, La Plata, Cincinnati, Nice, Johannesburg, Bern, and Algiers. This gives an idea of the international aspect of the work.

There appear to be 1565 numbered asteroids. Beginning with 1950 data, the ephemerides are now computed for dates at 10-day intervals (instead of 8-day intervals), with the result that an opposition ephemeris now covers 7 weeks 2 days, with the possible extension of at least 20 days more if an extrapolation is effected on the given ephemerides.

We also have a similar volume for 1950, as published by the Russian headquarters. This was completed too soon to incorporate the change to 10-day intervals. Commonly, there is but a small discrepancy—if any—between an ephemeris in this collection and the corresponding one in the book published here.

The following two 10th-magnitude asteroids are the brightest of the ones next in order in our series.

ASTEROID EPHEMERIDES

0^h U.T. Equinox 1950

230 ATHAMANTIS			185 EUNIKE		
1949-50	α h m	δ ° ′	1949-50	α h m	δ ° ′
Dec. 10	7 27.3	+12 37	Dec. 20	8 2.5	− 3 45
20	7 19.4	+11 56	30	7 55.6	− 3 14
30	7 9.4	+11 28	Jan. 9	7 47.3	− 2 16
Jan. 9	6 58.7	+11 12	19	7 38.5	− 0 55
19	6 48.5	+11 8	29	7 30.1	+ 0 45
29	6 40.0	+11 15	Feb. 8	7 23.1	+ 2 38

Hayden Planetarium, American Museum of Natural History, New York, 1949 November 21.

Occultation Predictions for January, 1950

(Taken from the *American Ephemeris*)

Date 1950	Star	Mag.	IMMERSION Greenwich C.T.	IMMERSION *a*	IMMERSION *b*	IMMERSION Angle E from N	EMERSION Greenwich C.T.	EMERSION *a*	EMERSION *b*	EMERSION Angle E from N
			h m	m	m	°	h m	m	m	°
OCCULTATIONS VISIBLE IN LONGITUDE +72° 30′, LATITUDE +42° 30′										
Jan. 3	406 B.Taur	5.6	0 25.1	−0.8	+1.9	70	1 39.9	−1.5	+1.0	267
5	4 Canc	6.2	8 9.8	−1.6	−0.8	85	9 12.4	−0.3	−2.5	321
11	α Virg	1.2	14 54.3	−0.7	−0.8	130	15 55.6	−0.4	−1.7	284
12	40 H.Virg	5.1	10 24.3	−0.6	−1.2	158	11 27.8	−2.1	−0.1	274
21	50 Aqar	5.9	0 2.0	−0.1	0.0	48	0 59.2	0.0	−0.8	251
28	104 B.Taur	5.5	5 41.3	+0.5	−3.3	137	6 17.0	−0.8	+1.0	207
28	BD+23°563	6.1	6 12.4	−0.2	−0.8	73	7 9.8	+0.4	−1.3	272
30	107 B.Auri	6.5	5 20.7	..	..	160	5 50.6	..	..	209
31	49 Auri	5.0	5 25.9	−1.5	−0.6	76	6 30.1	−0.3	−2.4	309
31	134 B.Gemi	6.5	20 31.4	−0.1	+0.5	123	21 17.2	+0.4	+1.9	236

Date 1949	Star	Mag.	IMMERSION Greenwich C.T.	*a*	*b*	Angle E from N	EMERSION Greenwich C.T.	*a*	*b*	Angle E from N
			m	m	m	°	h m	m	m	°
Occultations Visible in Longitude +91° 0′, Latitude +40° 0′										
Jan. 3	406 B.Taur	5.6	0 13.4	+0.1	+2.3	48	1 11.8	−1.1	+0.7	286
5	ω Canc	5.9	7 8.6	−2.6	+1.3	68	8 8.6	−0.8	−3.4	335
5	4 Canc	6.2	7 41.7	−1.6	−1.5	120	9 1.5	−1.6	−1.4	285
11	α Virg	1.2	14 41.6	−1.0	−1.9	144	15 46.4	−1.1	−1.6	279
20	50 Aqar	5.9	23 57.5	−0.3	+0.6	32	0 57.0	−0.6	−1.0	258
26	19 Arie	6.0	5 43.6	+0.3	−3.1	125	6 20.6	−0.5	+1.6	198
28	BD+23°563	6.1	6 10.5	−0.4	−1.6	100	7 13.0	−0.4	−0.6	244
31	49 Auri	5.0	4 55.4	−1.8	−1.1	104	6 18.0	−1.6	−1.2	276
Occultations Visible in Longitude +98° 0′, Latitude +31° 0′										
Jan. 2	406 B.Taur	5.6	23 57.9	+0.2	+1.7	60	0 57.2	−0.7	+0.9	273
5	4 Canc	6.2	7 54.3	−0.9	−4.4	164	8 49.6	−3.5	+1.5	241
11	α Virg	1.2	14 55.1	−0.8	−2.7	169	15 47.4	−1.8	−0.8	260
20	50 Aqar	5.9	23 48.2	−0.8	+0.5	48	0 57.2	−0.6	+0.1	237
28	23 Taur	4.2	4 20.0	−2.0	+1.4	45	5 31.2	−1.2	−2.2	288
28	η Taur	3.0	5 27.7	..	..	11	5 56.3	..	..	327
28	27 Taur	3.8	6 4.7	−1.3	+0.4	53	7 6.1	−0.1	−2.0	291
28	28 Taur	5.2	6 17.9	−1.7	+2.1	27	6 58.5	+0.4	−3.7	316
28	BD+23°563	6.1	6 35.3	..	..	151	7 0.3	..	..	193
31	49 Auri	5.0	5 0.4	−1.8	−3.7	146	6 4.3	−3.1	+1.7	233
Occultations Visible in Longitude +120° 0′, Latitude +36° 0′										
Jan. 1	36 Taur	5.7	1 53.6	−2.6	−0.3	121	2 31.8	+0.8	+4.4	184
3	136 Taur	4.5	1 3.2	−0.6	+0.1	126	1 41.5	+0.7	+2.7	209
13	64 G.Libr	5.7	14 25.7	−1.2	−0.6	134	15 42.4	−2.0	−0.4	288
28	23 Taur	4.2	3 56.9	..	..	2	4 35.1	..	..	311
28	27 Taur	3.8	5 31.2	−1.9	+1.4	44	6 42.9	−1.3	−2.2	287
28	28 Taur	5.2	5 48.9	..	..	19	6 34.3	..	..	312
28	BD+23°563	6.1	5 58.6	..	..	144	6 32.2	..	..	190
31	49 Auri	5.0	3 55.7	−2.3	−0.6	119	5 13.8	−2.1	+1.8	240
31	54 Auri	5.8	6 47.0	−2.9	+2.4	49	7 39.9	−0.8	−4.3	333
31	25 Gemi	6.5	7 56.0	..	..	44	8 36.5	..	..	343

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

There is considerable doubt in the minds of many observers, as well as men who deal with meteors from the standpoint of theory, as to how valuable tables of radiants, derived from current observations, may be. The writer will agree

with critics that very many of the minor radiants, published by him and derived from mapped meteor trails sent in by members of the A.M.S., represent chance intersections of trails or errors of plotting. Nevertheless, it seems to him quite improbable that, as a rule, the projections of 4 or more meteor trails, plotted on one night by a fairly trained observer, should intersect in a very small area when so far as we know there would be no reason for them to do so unless their paths in space were approximately parallel. This is further fortified in that, in most cases, the observers had no idea where such areas of intersection would be. I think it indeed very probable that many such radiants come from a relatively small group of meteors and may never be seen again. However, only by publishing what we find and comparing the positions of such radiants, seen near the same dates, can we hope to determine those streams which appear annually and therefore merit attention in the future. Hence while admitting that a large percent of our published radiants may be spurious or may represent single appearances—in either case being of no value—yet by examining our tables we should find valuable information about streams which do return, not only the rich ones but also those properly called minor. In accord with these remarks, a table of radiants, just derived at the expense of much work on my part, follows.

A.M.S. No.	Date 1948		α	δ	No. of Meteors	Wt.	Observer and Remarks
3035	Dec.	28.85	122°	+15°	4-5	F	J. Kn
3036	Dec.	28.85	170	+22½	4+	G	J. Kn
	1949						
3037	July	21.79	3	— 4	8±	F	J. Kn, v. large area
3038	July	26.79	3	+32	5-6	G	J. Kn, 7, 10, 527
3039	July	26.79	13	+38	5-7	F.G.	J. Kn, 11
3040	Aug.	1.79	36	+17	6-7	G	J. Kn
3041	Aug.	1.79	47	+12½	5	G	J. Kn
3042	Aug.	21.81	47	+54	5	G	J. Kn
3043	Aug.	1.79	48	+62	3-4	G	J. Kn
3044	Aug.	20.79	51	+45	4+		J. Kn, 2 on Aug. 16
3045	Aug.	21.81	58	+35	5—	F	J. Kn
3046	Aug.	20.79	60	+22½	4-7	F.G.	J. Kn
3047	Jan.	8.85	193	+32	4-6	F.G.	J. Kn
3048	July	26.79	222½	— 8	3	G	J. Kn
3049	Jan.	2.89	226	— 6	3	F.G.	J. Kn
3050	Jan.	2.89	227	+50	30+	F.G.	J. Kn, v. large area, Quadrantids
3051	Apr.	19.79	238	+26	4+	F.G.	J. Kn
3052	Apr.	20.3	274.5	+21.3	4	V.G.	J. Kn
3053	July	28.79	306	— 4	4+	F	J. Kn, 1 on July 26
3054	July	26.79	328	—23	4+	F.G.	J. Kn, 1483, 1493, 1494, 2779
3055	Aug.	24.76	343	+63	3		J. Kn, 1189?
3056	Aug.	1.79	345	— 7	7	G	J. Kn, 198?, 202, 1530
3057	Aug.	1.79	359	+14	5	F.G.	J. Kn,448, 1222, 1226

They are all from the maps of Jeremy H. Knowles of Marblehead, Mass., and are from observations submitted within the past twelve months. The data in table call for no comment except that in the *Remarks* column a very partial examination of other A.M.S. published radiants give some probable confirmations. Many more could doubtless be found by a closer search which I have not had time to make.

The rest of the Notes will be taken up by a discussion of certain very interesting observations, recently made. First let us quote from a *Hydrographic Bulletin*, U.S.N. "Second Officer Thomas Walsh of the American S.S. Helen Hunt Jackson, Captain C. L. Smith, reports as follows: "On August 18, 1949, at

0910 G.C.T. in lat. 26° 23′ N., long. 168° 50′ W., two meteors were seen to collide in the sky about 35° above horizon on a bearing of 135°. One meteor was falling on a course of about 080°, the other about 180°. Upon contact of the two meteors the sky lighted up in a bright flash for approximately 3 or 4 seconds, then bright falling pieces like those of a rocket bursting in air were visible falling seaward, fading out and disappearing before contact with the sea. These meteors were also observed by Seaman Alonza Adams who was lookout in the bow at the time . . . partly cloudy sky."

Of course the *chance* of two meteors colliding in our atmosphere is probably one to trillions, to hazard a guess surely too low, yet anything of this nature *can* happen. It is indeed most rare that two meteors, seen simultaneously, seem to cross each other's path. Yet the above report seems carefully made and the data fully reported. Also it is checked by a second observer. As far as my recollection goes it is, however, quite unique.

The second observation is that of a meteor which shot directly at the Moon, then just past first quarter, and comes from our able and active observer P. Barnes of Lyallpur, Pakistan. Along with a full description there is an excellent diagram from which I have measured off certain angles. His description follows: "View in small telescope (20 x 37 mm terrestrial) of First Quarter Moon on 4 June '49 I.S.T. 20:08 ±, giving track of telescopic meteor . . ." I have measured as follows: angle of path with respect to terminator 30° where angle is counted south-north-entrance point. Latter point on the limb is about 50° from south pole of Moon. Path seen in field of view, up to limb, is 13′ long. Now quoting again: "Color: Deep yellow, in contrast with silver-yellow of . . . lit surface. Magnitude: Apparent in 'scope to 2nd naked eye magnitude. Duration: From entry into field to its being lost against Moon's light about 2¼ seconds. Other Remarks: No streak. Did not appear when expected to cross terminator, or across darker surfaces of (Mare) Nectoris, Tranquilitatis and Serenitatis. Just a chance observation while . . . finely focussing . . . on lunar features." This is his number 455 for 1949, giving some idea of how much time and interest he is giving to the observation of meteors.

The third observation was made by John J. O'Neill of Freeport, L. I., N. Y., who is well known to all of us who attend the larger scientific conventions. As I have several letters from him on the subject, the more important points will be condensed and quoted. "Rapidly Moving Dark Object Transiting Moon . . . Oct. 2, 1949, 9:30 ± 10 P.M., E.S.T. . . . Freeport, L. I., N. Y. . . . 4″ refractor, 40 x. Sky clear, seeing conditions excellent. . . Path of object: Would cut (full disk) . . eastern limb at 22° Lat. N and western limb at 37° Lat. N . . . path . . . straight. Size . . . 6″ . . . major axis 6″, minor axis 3.5″. Approximately rectangular prism with well-rounded corners. . . Major axis made an angle of about 10° with line of flight, forward end tilted towards south . . Duration of transit between 1.5 and 1.75 seconds. . ." The measurements were made on an 18-inch map of the Moon, evidently with much care. The approximate position of the latter was R.A. $21^h\,57^m$, Decl. −16° 54′. Moon's age was about 10.5 days, illuminated fraction 85%, position angle of axis 341°, and of terminator 336°. These data are from *American Ephemeris*. From the drawing we find that the object entered from the dark, *i.e.*, eastern limb and left the illuminated or western limb. The path, on drawing, makes an angle of 83° with axis of terminator. Also as the geocentric diameter was 1796″, we measure the path as 18′ 57″ long or about 19′. From the observation we assume time of transit as 1.625 sec., hence the angular velocity is 700″ per second. At this rate

a whole revolution in a circular orbit would be made in 1296000/700 seconds = 1851 + sec. or 30.85 minutes. As by Kepler's third law this is less than the period of a satellite at Earth's surface, evidently the possibility of a small satellite would at first glance seem to be ruled out. However the above assumes motion as seen from center of Earth, which is not the case, so a new set of assumptions must be made.

Let us first use radians. As the object moved 19′, then its distance (if horizontal which is the minimum) would be 3438/19 = 181 times length of said path. As the object was dark, we could not assume it to be lower than 120 miles or friction from our atmosphere would surely make it glow. Also as it appeared at the low altitude of about 31° we should divide 120 by sin h = 0.51 to get its approximate distance from observer. Then its minimum path would be about 1.3 miles long and velocity 0.8 miles per second. Such a velocity is impossibly low for a meteor, hence for our assumption of distance to be true, the object would have to be coming at a small angle with the line of sight to secure the usual meteoric velocities. At a distance of 240 miles, 6″ would give a length of 37 feet. As there is nothing impossible in there being meteorites of this size in space, I would be disposed to consider it a body in our atmosphere except that it would, under these conditions, have had to come on down and become a most brilliant object. This did not occur. If we now compare 700″ per second with the Moon's mean angular velocity of 0.55″ per second, we see it over a thousand times larger. This merely proves what we already knew, that the body was between us and the Moon. I then calculated the angular velocity for a satellite in a circular orbit for R = 6000 and for R = 5000 miles. These are approximately 139″ and 183″ per second, seen from Earth's center. But if they passed through zenith of a station they would be 2000 and 1000 miles distant only. Hence these numbers would become 417″ and 914″ per second. But the Moon's altitude was 31°. Therefore for the observer in the second case the angular velocity would be 914″ sin 31° = 467″, about two-thirds that of the observed velocity of 700″. We can not, however, have a satellite nearer than 1000 miles of the Earth's surface, as there is reason to believe that definite atmospheric friction would begin lower than that figure if not much higher. I think we must rule out the satellite hypothesis as one that near, at least by analogy with others, would have a circular orbit, unless we admit an error of fully 50% in the observed time. Of course that latter is not impossible by any means. But we know of no close retrograde satellites where the larger are direct, and this would have to be.

But if we assume that the object had heliocentric parabolic velocity and was moving retrograde and almost parallel to the plane of the ecliptic, then its relative velocity would be near 44 miles/sec and in 1.625 sec. it would move 72 miles. Earlier, by radians, we saw that the distance would be 181 times as great, so under this hypothesis a distance of roughly 13,000 miles would fit. Please understand that this is the roughest approximation but it does indicate that a body, moving retrograde and of about 0.3 miles long, would agree with the observation if it passed us at the distance stated. As to whether such a body, not in the Earth's shadow, would look dark against the Moon, is of course open to serious question. The above are but a few of the possibilities, but perhaps the most obvious ones.

Flower Observatory of the University of Pennsylvania, Upper Darby, Pa.,
1949 November 17.

Contributions of The Meteoritical Society

(Known Formerly as The Society for Research on Meteorites)

Edited by FREDERICK C. LEONARD
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The Mechanism of the Sounds from Meteors*

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ABSTRACT

This paper reviews records of sounds from meteors that were heard simultaneously with the appearance of the meteors. Such sounds are carried presumably by electromagnetic waves. A number of different conceivable mechanisms for the generation of the radiation, which have the necessary characteristics, are considered. It is concluded that the most likely mechanism involves the radiation that originates in large numbers of air molecules that are ionized by the impacts of the invading meteorites.

It is well known that, some time after the appearance of a large meteor or fireball, a dull, booming thunder usually reaches the observer. This thunder is often accompanied by violent explosive sounds. The time interval between the appearance of the meteor and the sound is the proper one (a matter of several minutes), based on the usual value of the velocity of sound (1100 feet per second) in air and the distance of the object. Cases are recorded of the sound's seeming to roll back along the track of the meteor, as is to be expected in the case of an approaching meteor, for it far outstrips its sound waves. These effects are all what one would naturally expect, and the vibrations are generated clearly by the physical impact and the heat of the invading meteorite against the air. It is, however, a remarkable fact that such meteors generate another sort of sound, which *accompanies* the appearance of the meteor. The observer's attention is often first directed to the phenomenon by this sound, which causes him to look up and see an object 50 to 100 miles away whose visibility lasts, at most, a matter of seconds. Individual instances of this sound have been recorded in the literature, and it seems desirable to bring together a number of those records of the phenomenon itself before venturing a tentative explanation of the causative mechanism.

Biot, as quoted by Merrill,[1] refers, in connection with the fall of April 26, 1802, to "a hissing noise like that of a stone discharged from a sling" being heard "at the time . . . a multitude of mineral masses exactly similar to those distinguished by the name of meteor[it]ic stones were seen to fall." There is here reported merely the simultaneity of the sound and the *fall*, but the "hissing noise" is, as we shall see, significant.

Dr. E. A. Wülfing, of Heidelberg, is quoted by Merrill[2] as including in a questionnaire for observers of large meteors the following: "Did any sounds,

*[The term *meteor* as used in this paper means an incandescent meteorite in flight in the Earth's atmosphere and its concomitant luminous phenomena.—ED.]

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as crackling and hissing, come very soon, *i.e.*, within a second, after the flash, to the ear of the observer?," thus indicating that he wanted further evidence on reports of such sounds.

Udden[3] reports a Dr. F. M. Pottenger and others as having "their attention . . . called *first* by a hissing sound . . . and then by a bright light" to a great meteor that appeared in Indiana, in about 1880. "Upon looking to the northeast, they *then* saw a large ball of fire passing across the heavens" (*italics* supplied).

In connection with the Texas meteor of October 1, 1917, Udden[3] reports: "Several persons relate [that] they heard a whizzing sound and that this was simultaneous with the appearance of the meteor itself." This sound is compared to "the sound from 'escaping steam,'" "a spewing noise, like that of a small amount of powder," "the swish of a whip in the air," and it is described also as a "hissing, whizzing sound," a "whirring sound," and a "faint, buzzing sound."

Sellards[4] made an extensive investigation of such reports in connection with the Texas meteor of June 23, 1928, in describing which the new adjectives "whining," "shhh," and "sizzling" are added to "whizzing." Five observers whom he quotes said that their attention was first called to the meteor by this sound.

Olivier and Monnig[5] state that Logan, a member of the American Meteor Society, "who has had considerable experience in astronomic work, says he heard a distinct and long-drawn-out 'pop' just as the object [the Texas fireball of August 8, 1928] appeared." Another observer of this meteor reported to them that "there was a hissing or whirring noise." To quote the authors: "Merely because one does not have a good explanation to offer is no reason for denying that a certain phenomenon took place."

Wylie[6] collected a large number of observations of the Illinois fireball of July 25, 1929. He says: "Many letters report a swishing or hissing sound . . . there is no mention of an appreciable interval of time between the appearance of the meteor and the hearing of the sound." Since others in the same community definitely reported "that no sound was audible," and since "the interval should have been minutes," this author says that "none of these sounds can be accepted as from the meteor." Other authorities[5,8] started out with the same skepticism, but were finally convinced by the number and the reliability of the reports that they and others received.

In connection with the great meteor of March 24, 1933 (from which dropped the Pasamonte Ranch, Union County, New Mexico, meteorites), Nininger[7,8] reports that one man was attracted out of a house by the sound, and saw the fireball. He adds to our list the adjectives "humming," "rustling," and "crackling," and comparisons to "a heated iron being plunged into cold water" and "frying bacon."[8] He states[7] that the phenomenon was reported in connection with all the meteors he has investigated and that he has encountered "literally hundreds of [such] reports."[8]

Finally, LaPaz[9] mentions "unearthly whizzing sounds" in connection with the fall of the Norton County, Kansas-Furnas County, Nebraska, meteorites on February 18, 1948, and says that the hearing of such sounds was "notably true" in connection with that fall.

This mass of data was gathered over a generation, by these 7 leading American investigators, from many hundreds of observations of the 7 fireballs referred to, and likewise from many others. Such a weight of evidence of a meteor's audible accompaniment can scarcely be dismissed as a product of the imagination of the

visual observers. This sound has been called *"ethaërial,"*† and radio propagation has been suggested in connection with it.[8] As far as we are aware, no mechanism has been suggested to explain its origin. It is the purpose of this paper to consider various mechanisms whereby the phenomenon might conceivably take place and briefly to examine each one. Certain features common to all of them will be treated first, and the hypothesis believed to be the most favorable will be put forward last.

As any one of these large meteorites hurtled thru the air, eddies were presumably formed in its wake, as they always are in the wake of a body moving at a high velocity thru a fluid. The eddies were formed successively on each side of the meteorite, and they detached themselves and flowed away from it just as they do from a canoeist's paddle in the water. Thus the air at the surface of the meteorite, in addition to its enormous steady, average, relative velocity, had a smaller alternating velocity that varied with a frequency that may well have been within the audible range. Moreover, the meteorite was unquestionably a source of electromagnetic radiations. We know that it was brought to incandescence by its passage thru the air and therefore gave off both light and heat. Whipple[10] has calculated that, of the meteorite's kinetic-energy loss, due to retardation by the air, one half goes to heating the meteorite and one half to the movement and agitation of the air. The alternating air motion, due to the eddies, might be expected rapidly to heat and to cool the surface of the meteorite on alternate sides, and thus to affect the radiation from it, modulating this at an audio-frequency. The electromagnetic radiation thus modulated travels naturally with the velocity of light. Upon reaching any suitable receiver and detector, the low-frequency component would be made manifest.

Reduced to its lowest terms, a radio receiver consists of an antenna, a detector, and a mechanical vibrator coupled together in such a way that, when it receives audio-frequency-modulated electromagnetic waves, it delivers audio-frequency acoustic waves. Crystal sets were used with success before the advent of vacuum tubes. It has been reported[8,11] that a kitchen range may have all these properties; possibly a barbed-wire fence or a sheet-metal garage also may have them. The non-linear element necessary for detection is probably accounted for most simply by a ground connection whose resistance is not wholly constant. If, then, any substantial part of the radiation from the meteorite is of radio frequency, any one standing near such objects might well hear the meteorite in its passage and see the meteor at the same time, since the propagation velocity is the same for both signals, namely, 186,000 miles per second. Particularly at a time of excitement, such as the moment of the passage of a meteor, the ears are not sufficiently directional to note that the sound heard does not come from the direction of the meteor but from a neighboring terrestrial and homely object.

In considering various conceivable sources of receivable radiations, the first mechanism that comes to mind is based on the classical theory that every incandescent body emits a spectrum of electromagnetic radiations that contains components of all wavelengths from zero to infinity. An equation is known[12] that relates the emission per unit area of the surface of a hot body per second at a particular wavelength to the wavelength and the temperature of the surface. This equation and approximations to it have been independently derived from theoretical considerations by a number of workers, including Planck, Jeans, and Rayleigh. It has been checked in the visible, ultraviolet, and infrared ranges, tho no

†[A more euphonious term (and a word less liable to be confused with *ethereal*) would be *ethrial* (pronounced ēth′-rĭ-ăl).—Ed.]

very satisfactory check in the radio-frequency range is believed to have been made. At the lower frequencies, the radiated power varies approximately as the square of the frequency. Thus, by far the larger part of the power is radiated in the visible and ultra-visible ranges. Specifically, for a body at a temperature of about 3,000° K., it may be computed from this equation that the proportion of energy radiated at wavelengths longer than 1 cm. is about 10^{-11}; at wavelengths longer than 10 cm., 10^{-10}; and at wavelengths longer than 100 cm., 10^{-17}.

From the most sanguine reports of the brilliance of one of these meteors, we may compare it with a 100-watt lamp-bulb at a distance of 50 feet, and this comparison we believe to be more than generous. Disregarding the loss of energy from the lamp by conduction, we find that, if the meteor was 50 miles away when seen and heard, its total radiated power was

$$P = 100\ (50 \times 5280/50)^2 = 28 \times 10^8 \text{ watts,}$$

or about 3 million kilowatts, and therefore that its power at wavelengths of 10 cm. and over was of the order of $30 \times 10^{8-14} = 30 \times 10^{-6}$ watts, or 30 microwatts. Even at wavelengths longer than 1 cm. (far too generous, we think, for the capabilities of a barbed-wire fence as a receiver), the radio-frequency power was only 20 milliwatts, and at wavelengths of a meter or more, it was 0.03 microwatt. Thus, tho there are no conceptual difficulties with the theory of radio-frequency radiation based on incandescence, the quantitative difficulties seem to be insurmountable. For this reason we, who conceived the foregoing hypothesis in 1934, have refrained from publication until now.

The large amount of available energy, about 3 million kilowatts, just calculated, tempts one to indulge in speculations as to the use of a substantial part of it in the band where the power output of the meteor as a generator was greatest—the visible range or thereabouts. The eddies that alternately heated and cooled different portions of the surface presumably modulated the emitted light. If the eddies were of audible frequency, we have an audio-frequency-modulated light-wave. But what was there on the ground to receive it? There has been as yet no evidence that the barbed-wire fence has photosensitive properties or that it can operate as a detector for modulated light. Even on the very extreme hypothesis that certain eddies operate to modulate the light at a radio-frequency, the resultant being then remodulated at the audio-frequency, we have still to discover a device located near the observer that will respond to modulated light rays as distinguished from modulated radio waves. To obtain any modulation product of the desired frequencies, we must imagine that the eddies operate at frequencies of the order of light frequencies—an assumption that is surely out of the question on aerodynamic grounds. But is there not some mechanism other than the eddies that might give rise to radio-frequency energy by modulation? If two different parts of the surface of the meteorite were glowing at two slightly different temperatures, they must have emitted light whose strongest components were of slightly different wavelengths. If the frequency difference was of the order of a radio-frequency, and they could somehow be modulated together, the resulting lower-side band would have the desired characteristic, at the same time as adequate energy. Associated with the intense heat-gradient in the neighborhood of the meteor there may well have been a variation in the index of refraction of the atmosphere from point to point; but that is far from being the sort of non-linearity required for modulation, nor is there any indication that a barbed-wire fence or any neighboring terrestrial object has the necessary light-detecting properties. Whether by reason of the possibly exceedingly high potential of outer

space from which it reached our atmosphere, or by reason of friction with the atmosphere itself, the meteorite may well have accumulated a very high electric charge. As it approached the Earth, it may have suffered successive discharges, either to the Earth or to the air. We might expect these discharges to give rise to disturbances of an aperiodic nature, like the static discharges heard in a radio receiver during a storm. Some observers do report crackling noises. In some cases the noise has been likened to the sound of frying bacon, but the majority of observers describe the noise as more like a whiz or a whir or a roar, such as the roar of an airplane. Noises of this character are not suggestive of individually separate discharges; furthermore, the wiping-off of the fused outer skin of the meteorite, which is the process that keeps its interior cool, presumably takes with it any accumulated surface charge, thus preventing any great rise in the body's potential.

Ever since Jansky[13] first observed radio energy that appeared to originate in the Milky Way, numerous workers[14–19] have noted similar radiations that reach the Earth from various points of the Galaxy, as well as from the Sun. Altho the solar radiations were soon correlated with sunspot activity, the origins of the sidereal radiations were at first in some doubt. It is now believed[20] that Jansky was correct in his original suggestion that they originate in the ionization of atoms such as hydrogen, by collision with free electrons. In the sparsely populated regions of interstellar space, the density of matter is about one particle per cubic cm.[20] At heights of from 10 to 50 miles above the Earth's surface, the density of matter is about 3×10^{18} particles per cubic cm. It has been estimated[21–26] that the passage of a meteorite thru this air results in the formation of a "train" of partly ionized air of surprisingly large volume, namely, a cylindrical column 1 km. in diameter and 100 km. in length,[25,27] in which the density of ionized particles is about 10^6 per cubic cm.—and this for a minute meteoritic particle weighing only ¼ gm. This large volume of air, absorbing in the form of ionization a large fraction, approaching one half,[10,21] of the meteorite's energy of motion, may reasonably be expected to give off radiation of the intragalactic type, and, by virtue of the far greater density of ionizable particles, in enormously greater amount per unit volume of the ionized air mass. Specifically, the ion density is of the order of 1 million times as great. The volume of the train is, of course, small compared with the volume of space in which the intragalactic radiation has its source, but the distance to be covered is much less, being measured in tens of miles as compared with thousands of light years. These radiations are independent of frequency,[20] thus greatly favoring the ratio of radio frequencies to light frequencies, as compared with the radiations from the incandescent body of the meteorite itself. Furthermore, such radiations are randomly distributed as to amplitude and phase, so that, after transformation to acoustic waves by a detector, they would appear as "noise," generally of the character described in the reports,[1–9] and pitched approximately in the range at which the receiver or the hearer's ears are most sensitive.[30] If this sort of thing were the mechanism by which the radiations are generated, and we suggest it as the most likely one, the mechanism of audio-frequency modulation by air eddies, previously suggested, becomes unnecessary, tho it remains helpful. The foregoing hypothesis is put forward in qualitative form only, and more with the hope of promoting discussion than with any pretense of finality. The possibility must not, of course, be overlooked, that the meteor train acts not only as an energy source but also as a reflector of radio waves originating at terrestrial radio transmitters. It is known to act in this way, and whistles and squeals in receivers have been

definitely correlated with meteors.[24-30] It is noteworthy, however, that there exist records, including those previously referred to, of ethaërial sounds that antedate commercial broadcasting stations.

The stimulation of discussions with Dr. A. M. Skellett, of the National Union Radio Corporation, who first suggested that the ionized train of air be examined, is hereby gratefully acknowledged.

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Azimuth Determinations in Meteoritics by Means of Time Readings*

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ABSTRACT

The inability of untrained observers accurately to measure and report, *e.g.*, the azimuth (bearing) of the point of disappearance, *L*, of a fireball is universally acknowledged. Even several weeks after the occurrence of a spectacular fireball, however, such observers are able to remember and to point out with some accuracy the position that *L* occupied in the sky. In this paper, advantage is taken of the layman's ability to recall and to sight at points in the sky like *L*, in order to develop a method by means of which the azimuth of a point, *P*, on the apparent path of a meteorite thru the atmosphere can be calculated, provided the observer simply reads and records a single watch-time, *T*, on some sunny day subsequent to the fall. This time, *T*, is the instant when the *true* Sun either has the same azimuth as *P* or differs from *P* in azimuth by 180°.

No fact in observational meteoritics is more firmly established and more universally deplored than the distressing inability of the untrained observer accurately to evaluate and report the bearing and elevation of, *e.g.*, the point of disappearance of a fireball in the sky. Because of the untrustworthiness of the data provided by the layman (that fortunate individual destined, because of his numbers, to see almost all of the falls that are witnessed by anyone, but doomed, by lack of training or interest or both, to be unable to report what he observes with any degree of accuracy!), it has become almost axiomatic with meteoriticists to obtain whenever possible instrumental measures made by a trained operator who receives instructions as to where to point his transit from the actual observer at the exact spot from which the latter's observation was made. It may be impracticable or impossible, however, to set up a transit at all stations from which good observations have been made (the night-guard towers in the "tech area" at Los Alamos, *e.g.*!), and always, in preliminary fireball investigations, what one wants is *speedily* to obtain reasonably dependable azimuths and altitudes rather than to waste much time and effort in obtaining highly exact measures on what may turn out to be a "barren" fall after all. As a result, a very large number of schemes have been devised by meteoriticists for the express purpose of enabling the untrained and often uninterested observer to improve his angle estimates.

Certain side conditions are imposed on those who evolve such schemes. To be regarded as feasible, a layman's aid must, *e.g.*, require procedures of little complexity and must avoid the shipment back and forth of model altazimuths and similar gadgets. Among the various plans tried out by me as Director, first of the Ohio Section of the American Meteor Society and later of the Southwest Section of that Society and of the Institute of Meteoritics of the University of New Mexico, the simplest and one of the most satisfactory consists in mailing out to eyewitnesses of a fall a standard government post card carrying on one side a bearing (azimuth) circle with the cardinal points marked on it, and, on the reverse, a semicircle (whose base coincides with an edge of the card), intended to represent the half of the vertical circle situated above the horizon of the observer that passes thru the point, *P*, on the fireball's path for which positional

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data are desired. (The use of a semicircle rather than a quadrant has been found necessary in order to avoid confusion in the mind of the layman in the case of fireball paths that pass from one side of the zenith to the other. If only a quarter-circle is available, the points of appearance and disappearance of such fireballs will both be *plotted* in the same quadrant of the sky, altho they were actually *seen* by the observer to lie in opposite quadrants.) The observer is instructed to orient the full circle so that the line, *NS*, on it lies in the meridian of the place of observation and then to draw a line from the center of this circle toward that point of its circumference having the same bearing (direction) as the observed position, *P*, in the sky. He is instructed also then to reverse the post card, and, keeping the base of the semicircle accurately horizontal (*e.g.*, by resting it on a carpenter's level or by use of a simple plumb-bob), to mark on it the position of a line of sight directed from the center of the semicircle to the point, *P*, in the sky.

To the trained astronomer, the operations just outlined will seem childishly simple; nevertheless, it has been found that an astonishingly large number of lay observers are confused as to just what they are supposed to do. Furthermore, even those able correctly to interpret the instructions given are found, because of carelessness or ineptness or both, to make disturbingly large errors in their determinations of angles. These errors are traceable to a variety of causes, of which the most important seem to be: (1) failure to place the *NS* line of the full circle accurately in the meridian of the point of observation; (2) failure to keep the base of the semicircle horizontal; (3) reversals of right and left (and even of up and down!) in the process of representing the directions of lines of sight to points in the sky by pencil lines drawn on the post card. As might have been anticipated, since all laymen have considerable experience with directions *in* the plane of the horizon, but very little or none with directions *inclined* to that plane, the errors made in altitude determinations are the largest and most erratic.

Since we may as well glean what small comfort we can from a bad situation, it may be pointed out that, from the viewpoint of meteoritics, it is fortunate indeed that the untrained observer performs better on azimuth than on altitude determinations. To facilitate the recovery of fallen meteorites, what is of prime importance is a considerable number of promptly reported, reasonably accurate measures of the azimuth of the last visible point on the meteorite's path thru the atmosphere (for some observers this may be the end point of the luminous path; for others, the point where non-luminous falling masses were last seen on their way toward the Earth). The meteoriticist's problem is, then, to devise a method that will produce more accurate azimuths, irrespective of whether or not it gives altitude data.

In what follows, we shall describe such an azimuth method, based on the following considerations: (1) for a considerable time after even the least impressionable layman has witnessed a spectacular fireball fall, he believes himself able to sight with accuracy at its point of disappearance in the sky (that his belief has justification is shown by the concordance of results obtained by use of *transit* measures made under the guidance of lay eyewitnesses); (2) from top to bottom of the social structure, there is one operation performable with precision by everybody, *viz.*, reading a timepiece. With these points in mind, let us require the lay observer to carry out the following extremely simple operations: (*a*) level a table- or box-top; (*b*) sight across this level surface at the point of disappearance of the fireball, marking the direction (azimuth) of the line of sight by sticking 2 pins vertically upright in the level surface and sighting thru them:

(*c*) read carefully the exact time when the shadow of the sunward pin falls centrally on the other pin. At this time, the azimuth of the *true* Sun is either (1) that of the point of disappearance of the fireball or (2) differs by 180° from the azimuth of the point of disappearance. (The observer has to specify only whether he sighted toward or away from the Sun in order for us to know which of (1), (2) is correct.) Our problem has, therefore, been reduced to the calculation of the azimuth of the *true* Sun at a specified *standard* time. Since the longitude and the latitude of the station of observation are known, the *Nautical Almanac* for the year in question then supplies all the information necessary for a complete solution of this reduced problem by means of the standard formulas of spherical astronomy.

Experimental tests, in which surveyed lines of known azimuth direction were used, showed that the errors introduced into the computed azimuths by faulty determination of the instant of central shadow (step (*c*)) were much smaller than those unavoidably occurring in step (*b*). A mimeographed sheet of instructions for use by the layman in carrying thru steps (*a*), (*b*), (*c*) was therefore prepared, and the method has been in use since the preliminary phases of the investigation of the great achondritic shower of 1948 February 18, in Norton County, Kansas, and Furnas County, Nebraska.[1]

As an aid to those who may wish to employ this method in connection with fireball surveys, a copy is here given (*post*) of the mimeographed sheet of instructions for its application that is now being used by the Institute of Meteoritics. In these instructions, the term "elevation card" refers to the post card described earlier in this article, which, however, no longer carries the full circle previously used in azimuth determinations.

INSTRUCTIONS TO OBSERVERS FOR FINDING THE BEARING (AZIMUTH) OF POINTS ON THE APPARENT PATH OF A FALLING METEORITE

Please read *all* of the following instructions *before* beginning observations.

1. Fig. 1 shows the 4 most important points on a meteorite's path thru the atmosphere. Listed in the order of their importance to the meteorite hunter, these

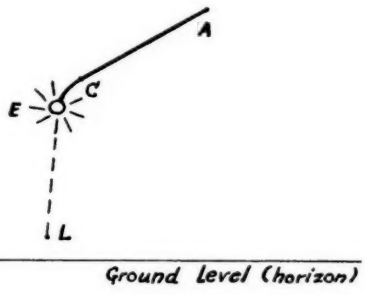

FIGURE 1

are *L*, the LAST point where meteorites, *i.e.*, solid masses, luminous or non-luminous, were seen dropping toward the Earth; *E*, the point where EXPLOSION or disruption occurred; *C*, the point where the straight-line path began to CURVE; and *A*, the point of APPEARANCE.

2. In order to find the bearing (azimuth) of *L*, wait until a sunshiny day

and then stick 2 pins, *A*, *B*, vertically upright in a level table- or box-top in such a way that the line of sight thru the pins points at *L* in the sky (or on the horizon, in case the meteorite seemed to fall all the way down to the Earth). Sometime in the course of the day, the Sun will be so placed that the shadow of the sunward pin *A* will fall on the other pin *B*. (Be sure that the pins are near enough together that the shadow of *A* will actually fall on *B*.) The whole problem is to determine the exact *standard* time, *T*, when the shadow of *A* falls centrally on *B*, for, from a knowledge of *T*, the bearing (azimuth) of *L* can be computed.

3. In using the foregoing method, the best procedure is to start so early that the shadow, *S*, of the sunward pin *A* falls slightly below the other pin *B* (Fig.

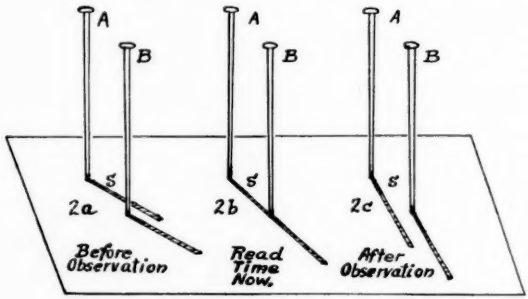

FIGURE 2

2*a*). As time passes and the Sun moves from east to west, the shadow, *S*, will approach the other pin, center on it (Fig. 2*b*), and then move away from it again (Fig. 2*c*). The trick is to record the exact time when *B* is in the center of the shadow, *S*, cast by *A*. This time is denoted by $T(L)$.

4. Enter your reading of $T(L)$ in the space left for it on the back of the *elevation card* (post card) inclosed herewith. Use a watch corrected by radio time or Western Union, if possible.

5. To help the computer in reducing your observations, please BE SURE to state on the back of the elevation card whether you had the Sun *in your face* or *behind* you when you sighted thru the pins at *L*. This check is VERY IMPORTANT.

6. *Caution!* If the 2 pins are nearly in an east-west line when they point toward *L*, then shadows may fall from one pin on the other near *both* sunrise and sunset. In this case, be sure to give only the time when an observer looking thru the pins TOWARD *L* sees the shadow of the far pin fall on the near pin.

7. In exactly the same way, determine the times $T(E)$, $T(C)$, and $T(A)$ for the other 3 points *E*, *C*, and *A*, and enter your readings on the back of the elevation card.

8. If you do not have time to make observations on all of the points *L*, *E*, *C*, and *A*, then kindly try to get the bearing of the most important point, which is *L*. *E* is next in importance to *L*; then *C*; and then *A*.

9. Please mail the stamped elevation card with all of your time and elevation observations written in on it to the Institute of Meteoritics, University of New Mexico, Albuquerque, New Mexico.

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The Theory of Micrometeorites (Abstract)*

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The term *micrometeorite* is here defined as an extraterrestrial body that is sufficiently small to enter the Earth's atmosphere without being damaged by encounter with the atmosphere. The limiting circumstance arises when the micrometeorite radiates energy rapidly enough that its temperature remains below its melting point as its motion is retarded by atmospheric resistance. The theory of the maximum dimension for such a particle with prescribed geocentric velocity and physical characteristics is developed in this paper. The solution depends upon the height-density relation adopted for the atmosphere. Two types of such relations permit explicit solutions for the limiting ratio of meteoritic mass to radiating area, or, if the particle is spherical, for the limiting radius. These atmospheric relations are (*a*) constant temperature and (*b*) constant temperature-gradient, both for constant molecular weight with respect to height. The second case appears to give a sufficiently accurate result for present needs.

The limiting radius for a spherical micrometeorite varies approximately as the fourth power of the melting temperature, the inverse cube of the velocity, the inverse logarithmic density-gradient at the point of maximum temperature, and the secant of the zenith-distance. Heights of maximum temperature increase with velocity, but lie in the neighborhood of the *E*-layer. For an iron meteorite at a velocity of 23 km./sec., the limiting spherical radius is 3-5μ. Long cylindrical particles may have a minor diameter of 4-7μ—in good agreement with the minor dimensions of the "wedge-shaped, opaque" magnetic particles that H. E. Landsberg associated with the great Giacobinid meteor shower in October, 1946 (velocity, 23 km./sec.). [*V.* H. E. Landsberg, *C. M. S.*, **4**, 50-2; *P. A.*, **55**, 322-5, 1947.] His larger, "round" particles (20-40μ diameter) may have been partially vaporized. This general agreement provides secondary confirmation of the assumed atmospheric relations at the 100-km. level.

The writer heartily encourages the collection and study of micrometeorites, as they may provide the only laboratory samples of cometary material; ordinary meteorites arise probably from a different source. Deep oceanic sediments, as suggested by the *Challenger Expedition*, polar snows, and even geological strata also may contain evidence of astronomical phenomena. [*V.* likewise an article entitled "Sprinkling Stardust," in *Time* magazine for Oct. 31, 1949, p. 64.]

The Committee on a General Catalog of Meteoritic Falls

In the "Report on the 12th Meeting of the Society," in the current November instalment of *C. M. S.*, it is recorded that "In the course of the Tuesday afternoon session [on September 6], President King read a letter from Dr. Harrison Brown of the Institute for Nuclear Studies of the University of Chicago, in which Dr. Brown invited suggestions from members of the Society on the compilation of a comprehensive catalog of meteoritic falls and of a complete file of meteoritical literature. In particular, Dr. Brown requested that President King appoint, or cause to be appointed, a committee of 3 persons to act as a liaison group be-

*[This is the abstract of a paper presented at the 1949 Autumn Meeting of the National Academy of Sciences, Rochester, New York, and is reprinted from *Science*, **110**, 438, Oct. 28, 1949. "A Preliminary Comment on Micrometeorites," also by Dr. Whipple, was read as paper no. 6 on the program of the 12th Meeting of the Meteoritical Society, Los Angeles, California, 1949 Sep. 6-8.—ED.]

tween the Society and the editorial committee of the project, which has been made possible thru a grant from the Rockefeller Foundation."

In accordance with that request, on 1949 October 21, President King appointed the following 3 fellows to serve as a Committee of The Meteoritical Society on a General Catalog of Meteoritic Falls: Curator L. F. Brady, Museum of Northern Arizona, Flagstaff, Arizona; Dr. Lincoln LaPaz, University of New Mexico, Albuquerque; and Dr. Frederick C. Leonard, University of California, Los Angeles (Chairman).

JOHN A. RUSSELL, *Secretary*

Editorial Notice to Authors and Readers

Responsibility for the propriety of publishing a paper in these CONTRIBUTIONS rests solely with the Editor of the Society, but responsibility for the views expressed in a paper and for the mode of expression rests wholly with the author or authors.—F.C.L.

President of the Society: ARTHUR S. KING, 925 Topeka Street, Pasadena 6, California

Secretary of the Society: JOHN A. RUSSELL, Department of Astronomy, University of Southern California, Los Angeles 7, California

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Honorary Recorder

Nova Scuti, 1949: The discovery of Nova Scuti, 1853*04*, was mentioned in these Notes for November. Fortunately, plates were secured at Harvard's Meteor Station at Las Cruces, New Mexico, late in July, which reveal that the

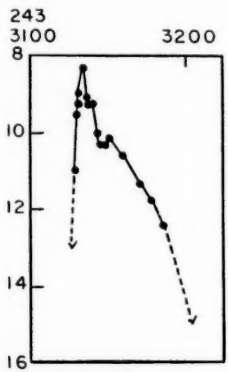

FIGURE 1
Photographic Light Curve of Nova Scuti, 1949.

nova was on the increase to maximum, magnitude 11, on July 31, whereas on the previous night it was invisible, fainter than magnitude 13.

Mr. Franklin E. Kameny, a graduate student at Harvard, has kindly furnished the photographic light curve of the nova, as observed by him from Harvard plates taken during July to October, 1949. It is to be understood that the magnitudes are approximate only, but sufficiently good to give an idea as to the early behavior of the star.

From less than magnitude 13 on July 30, the nova increased rapidly to magnitude 11, then steadily higher to nearly the 8th magnitude, attained probably on August 4. From August 5, the star gradually decreased in brightness to fainter than magnitude 15 on October 14. (See Figure 1.)

Here again the Harvard plate collection has proved to be most valuable, for Nova Velorum, 1940, and Nova Scuti both have been positively observed on rapid increases to maximum, through sharply defined maxima, and well down to their preminimum stages.

Nova Velorum, 1940: The recently discovered 1940 nova in Vela, found by C. J. van Houten of the Leiden Observatory, has, at the request of Dr. Oosterhoff, been examined by Dr. Dorrit Hoffleit on some 800 Harvard plates, taken between 1899 and 1948. The examination was especially detailed on the 1940 plates.

The star is located in R.A. $8^h\,55^m\,52^s$ and Dec. $-52°\,56'.7$ (1900), and increased rapidly in brightness from fainter than magnitude 14.5 (photographic) on April 4, 1940, to the 9th magnitude on April 18. The actual maximum magnitude may have been somewhat brighter and occurred a few days earlier.

On April 9, 1940, the star was of magnitude 11.5 (photographic) and on April 10, at magnitude 9.9. Thus we have observations secured on the increase to maximum, from which phase the star rapidly faded away to below 13th magnitude by the middle of June. From June to late in October the light fluctuated irregularly in brightness between magnitudes 14 and 16. The photographic light curve, as determined by Dr. Hoffleit, is shown in Figure 2.

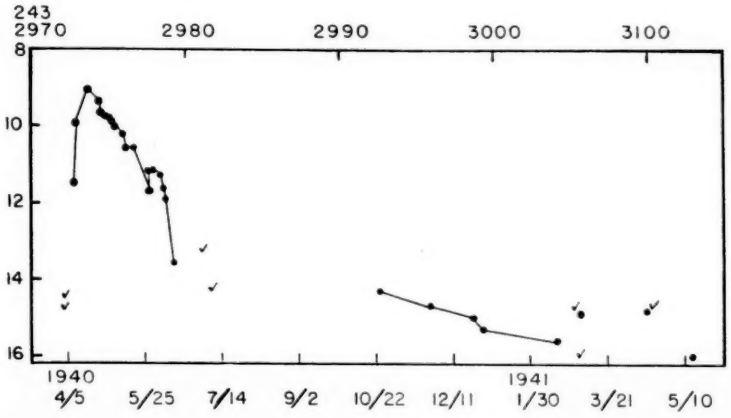

FIGURE 2
Photographic Light Curve of Nova Velorum, 1940.

Predicted Dates of Maximum of Long-Period Variables, 1950: Listed herewith are predicted dates of maximum for long-period variables which, on the average, attain a maximum magnitude brighter than 8.0. These values are taken from an AAVSO Bulletin soon to be published, which contains dates of maximum and minimum for nearly 400 variables. Copies may be obtained by addressing the AAVSO Recorder. In the successive columns are given the designation and name of the variable, the month and day in 1950 of the predicted maximum, and in the last column the *mean* maximum magnitude. Actual brightness at maximum may differ by a magnitude or more in some instances.

Design.	Name	Date of Max. m	d	Mean Max. Magn.
001032	S Scl	2	20	6.8
001755	T Cas	5	18	7.8
001838	R And	3	5	7.0
021403	o Cet	7	23	3.7
022813	U Cet	6	1	7.5
023133	R Tri	7	8	6.3
025050	R Hor	2	25	6.0
043263	R Ret	3	16	7.7
		12	19	
045514	R Lep	5	22	6.7
050953	R Aur	9	30	7.8
051533	T Col	2	25	7.6
		10	8	
054920a	U Ori	2	19	6.6
055686	R Oct	6	27	7.9
061702	V Mon	11	10	7.1
065208	X Mon	5	19	7.6
		10	21	
065355	R Lyn	5	14	7.9
070122a	R Gem	2	7	7.1
072708	S CMi	9	5	7.5
072820b	Z Pup	6	1	7.9
081112	R Cnc	4	18	6.8
082405	RT Hya	4	13	7.6
		12	21	
084803	S Hya	8	27	7.9
085008	T Hya	7	27	7.7
092962	R Car	3	17	4.6
093934	R LMi	9	8	7.2
094211	R Leo	1	2	5.9
		11	11	
		1	14	
100661	S Car	6	12	5.7
		11	8	
103769	R UMa	9	6	7.6
114411	X Cen	7	28	7.8
121418	R Crv	10	8	7.6
122001	SS Vir	9	30	6.9
123160	T UMa	3	12	7.9
		11	24	
		1	18	
123307	R Vir	6	12	6.9
		11	4	
123961	S UMa	3	14	7.9
		10	26	
132422	R Hya	6	12	4.6
132706	S Vir	5	14	7.1
133155	RV Cen	3	1	7.6
133633	T Cen	1	20	6.1
		4	21	
		7	21	
		10	20	
134440	R CVn	5	3	7.7
140959	R Cen	2	16	5.9
		9	16	
142539	V Boo	7	28	7.9
143227	R Boo	2	26	7.3
		10	8	
151731	S CrB	7	29	7.5
151822	RS Lib	4	23	7.7
		11	27	
152849	R Nor	3	15	7.2
153654	T Nor	7	12	7.4
154615	R Ser	6	23	6.8
154639	V CrB	4	30	7.4
162112	V Oph	7	20	7.5
162119	U Her	11	25	7.6
163266	R Dra	7	9	7.6
164715	S Her	4	11	7.6
164844	RS Sco	8	2	6.8
1650 30a	RR Sco	5	8	6.0
170215	R Oph	4	12	7.6
182133	RV Sgr	7	1	7.8
183308	X Oph	7	8	6.9
190108	R Aql	2	5	6.3
		12	24	
191019	R Sgr	4	29	7.2
193449	R Cyg	7	17	7.3
194048	RT Cyg	4	8	7.4
		10	15	
194632	χ Cyg	10	11	5.3
194659	S Pav	10	10	7.3
194929	RR Sgr	5	14	6.6
195142	RU Sgr	7	19	7.2
200938	RS Cyg	10	5	7.4
201139	RT Sgr	8	9	7.9
201647	U Cyg	4	12	7.6
204405	T Aqr	6	30	7.9
210868	T Cep	6	8	5.8
221948	S Gru	4	7	7.8
230110	R Peg	3	3	7.9
230759	V Cas	1	6	7.9
		8	22	
233815	R Aqr	8	18	7.3
235150	R Phe	1	4	7.8
		9	27	
235350	R Cas	1	26	6.5

Observations received during October, 1949: A total of 5,548 observations was received during October from 60 observers, as follows:

Observer	No. Var.	No. Ests.	Observer	No. Var.	No. Ests.
Adams	30	65	Kratz	2	2
Ancarani	23	49	Lacchini	159	456
Bogard	64	175	Lankford	24	54
Boone	16	17	LeVaux	11	12
Buckstaff	10	18	Lowder	19	29
Bufkin	12	13	Luft	7	26
Cain	9	9	Naef	4	26
Chandra	27	32	Oravec	75	259
Charles	24	45	O'Sullivan	5	32
Chassapis	104	221	Parks	19	23
Daley	2	8	Pearcy	160	166
Darling	16	21	Peltier	138	324
Darnell	2	7	Penhallow	38	60
Dillon	11	22	Pierson	89	150
Drakakis	66	760	Plakidis	7	11
Fernald	215	580	Reeves	2	4
Focas	11	14	Renner	198	211
Ford	15	15	Rosebrugh	18	162
Galbraith	1	13	Stahr	8	9
Greenley	73	152	Stevens	19	24
Haas	1	1	Tarbell	6	15
Hamilton	8	20	Tifft	9	25
Hartmann	155	180	Treadwell	3	3
Herring	44	57	Upjohn	59	60
Hiett	11	21	Venter	13	35
Holloway	14	27	Webb	18	24
Jackson	1	3	Weber	24	24
Kanda	4	34	Welker	46	69
Kelly	11	11	Wells	4	4
Kirchhoff	34	48	—		—
de Kock	129	611	60	totals	5,548

November 15, 1949.

Comet Notes

By DANIEL L. HARRIS III

Comet activity continues to be slow and at the present time there are no comets visible in small telescopes. The new periodic comet (1949 *e*), which was discussed in the November Comet Notes, is well situated for observation, but is fainter than the 13th magnitude. None of the periodic comets that are expected to return this fall (see October Comet Notes) have been observed as yet. Dr. Jeffers of the Lick Observatory has looked for COMET REINMUTH I, but found no object brighter than the 19th magnitude within one minute of time of the ephemeris position.

An interesting astrophysical observation pertaining to comets was recently announced by Dr. Whipple of the Harvard College Observatory. Three days after the Giacobinid meteor shower in 1946, Dr. Landsberg in Washington, D. C., found six small particles, averaging about one six-thousandth of an inch in diameter; it has been suggested that these may have had their origin in the comet. If this hypothesis is confirmed, we have the first samples of cometary material; although there are several meteor showers connected with known comets, no such association has been established for any of the meteorites.

Warner and Swasey Observatory, East Cleveland, Ohio.

Communications and Comments

Under this heading we shall publish from time to time such material as does not properly fall under any of the established headings of this journal. Here, too, may be found, when occasion arises, articles which the editor may not be willing to give sanction to but which, nevertheless, may be provocative of thought along new lines.

The Search for the Beginning

Dr. Wm. T. Skilling's interesting article* on Beginnings points out that according to Whipple and Spitzer, light pressure may be the force that collects cosmic dust particles, estimated at 1/50,000 inch in diameter, into cosmic clouds and thence with the help of gravitation into nebulae, planets, and stars. Light pressure is the force which keeps the tail of a comet constantly streaming away from the sun. Playing upon the side of the earth it amounts to 65,000 tons. The mutual shadows of two dust particles which are close together act similarly to a vacuum, forcing them together. Continued accretion finally forms solar systems.

This picture may be described a little more in detail. As an example, consider a huge box of tennis balls. Each ball represents a sphere of light-pressure emanating from a star at the center of the ball. The small spaces between the balls represent chambers of relative balance of light-pressure and the exact center of the space represents a point of balance.

Stars are not arranged like tennis balls in a box. They are of different sizes and at various distances from one another and if there were points of balance they would be constantly moving since every part of the universe is moving both actually and relatively.

This unevenness means that there are channels of relatively faint light-pressure throughout the universe and consequently chambers of relative balance exist.

Instead of considering that the cosmic particles coalesce anywhere in the universe, as is to be assumed from the Whipple-Spitzer theory, it would seem reasonable to expect that the particles may be impelled along the corridors like silt in rivers. Several such rivers may debouch into a chamber where the coalescing of particles would be expected to occur. The junctions may not be head-on, but off-center and thus possibly account for initiating the spiral motions of nebulae.

CHAPMAN GRANT

San Diego, California.

*A continued search for the beginning, *Scientific Monthly*, **68**, 84-90, February, 1949.

General Notes

The holiday season has a way of interrupting schedules. It will have that effect upon the issue of this magazine for January. A meeting of the American Astronomical Society is to be held in Tucson, Arizona, December 28-31. It is planned to have a report of this meeting in the January issue, which will delay the progress of the issue a week or ten days. It will, therefore, be mailed about January 15, we hope.

We extend Cordial Greetings of the Season to all our subscribers and readers. EDITOR.

The Rittenhouse Astronomical Society, of Philadelphia, held its monthly meeting on November 4, 1949, in the Randal Morgan Physics Laboratory, University of Pennsylvania. The speaker was Dr. Herbert R. J. Grosch, of Watson Computation Laboratory, New York City. His topic was "The Computational Approach To Astronomy."

Burrell Memorial Observatory

The Burrell Memorial Observatory at Baldwin-Wallace College, Berea, Ohio, is conducting an open-house schedule during this winter season for the benefit of the public. The series began in October and will be continued as follows: December 1, Venus, The Brightest Planet; January 26, Astronomy 1900-1950; February 23, The Amateur Astronomers Work; March 23, The Sun and Other Stars; April 27, Meteors, Comets, and Asteroids.

The Cleveland Astronomical Society

Some eighty-five members and guests heard Dr. Thornton Page of the McDonald and Yerkes Observatories on November 4. His topic was: "Beyond the Milky Way" (published in full elsewhere in these pages). The excellent presentation of the background and current developments in this extensive field was thoroughly enjoyed by those present.

PAUL ANNEAR, *Recording Secretary.*

Burrell Observatory, Baldwin-Wallace College, Berea, Ohio.
November 5, 1949.

Provisional Relative Sunspot Numbers for October, 1949*

1	68	11	183	21	67
2	115	12	198	22	113
3	150	13	182	23	118
4	198	14	145	24	106
5	196	15	156	25	95
6	222	16	153	26	71
7	190	17	140	27	71
8	195	18	77	28	88
9	180	19	55	29	110
10	166	20	63	30	124
				31	95

Mean Value for October
R = 131.9

*From the Zürich Observatory, furnished by Mr. Neal J. Heines.

Dr. Roscoe F. Sanford Retires

The Mt. Wilson and Palomar Observatories lost one of astronomy's top spectroscopists through the retirement of Dr. Roscoe F. Sanford on November 1 after more than 30 years of continuous service in Pasadena. On the afternoon of October 31 Dr. Sanford was honored at a reception tendered by the Mt. Wilson and Palomar Observatories staff and he and Mrs. Sanford were honored guests at a dinner at the University Club of Pasadena on November 2. His astronomical career has embraced two continents, and prior to coming to the Mt. Wilson Observatory in 1918 he was stationed in both Argentina and Chile in South America. Under the auspices of the Carnegie Institution of Washington, he went

to San Luis, Argentina, in 1908 and remained there until 1911. During that time he participated in determining accurate positions of southern hemisphere stars not observable in North America. Later, as a member of the Lick Observatory expedition to Santiago, Chile, he was engaged from 1911 to 1915 in making spectroscopic measurements of the velocities of stars seen in the southern hemisphere. In 1946 he again returned to South America as a guest of the Argentine government to attend the seventy-fifth anniversary of the founding of the Cordoba Observatory.

It was in 1918 that he joined the Mt. Wilson staff to continue spectroscopic investigations with the 60 and 100-inch telescopes there. He pioneered the application of high dispersion to numerous variable and double stars of special interest. His study of many of these has been in greater detail than ever before made and his work in the field of spectroscopy has brought him world-wide recognition.

His photographs of the spectra of cool red "carbon" stars whose atmospheres are loaded with carbon compounds are accepted as the best ever made in this field, and his observations have supplied a wealth of new information concerning the constitution and motion of these objects. Many of his finest spectrograms are included in an atlas which he has just completed. During his career he has written more than 130 articles on astronomy, most of them reports on his own investigations.

During World War II he worked at the Mt. Wilson Observatory on shutter tests of airplane cameras and flight formations of B-29's.

He is a graduate of the University of Minnesota and obtained his Doctor of Philosophy degree at the University of California in 1917. He is married and the father of five children, two boys and three girls. He is a member of the International Astronomical Union, American Astronomical Society, American Association for the Advancement of Science, and the Astronomical Society of the Pacific.

Dr. Sanford will devote most of his time following his retirement to writing and completing work which he now has underway.

Book Reviews

Skyshooting: Hunting the stars with your Camera, by R. Newton Mayall and Margaret L. Mayall. (174 pp. Illustrated. $3.75. Ronald Press, New York.)

Skyshooting will make an amateur astronomer out of almost any photographic enthusiast who has never before tilted his camera upward for night photography. This plainly written book deals in a most absorbing way with the photography of celestial objects. In reading it, I lived again my thrill when as a star hunter I caught my first meteor on a photographic plate. The chapters of greatest interest to the scientifically minded are those on meteors, comets, variable stars, aurorae, sunspots, and occultations.

A chapter, Fun for the Family, deals mostly with stereoscopic photography of celestial objects, explaining how three dimensional effects are obtained by combining exposures on moving objects such as comets, planets, and the moon. Meteor trails photographed simultaneously from stations some distance apart also make fine stereoscopic views.

One of the most important chapters is on the keeping of records. The date, the time, the region of the sky, the latitude and longitude of the observer, the exposure time, the type of emulsion used, and the details of development should all be carefully recorded, if the resulting picture is to be of scientific value.

As the reader advances from the simple experiments of photographing star trails, constellations, and meteors with a small camera, he will soon be making his own equipment to photograph sunspots and planets. Methods are described for discovering comets and variable stars as well as for determining their magnitudes, and data are given concerning the length of exposure and the type of film or plate to be used in photographing a great variety of celestial objects, from spots on the sun to craters on the moon. The illustrations are good, nearly all by amateur astronomers with homemade equipment. An appendix called The Library contains a list of good astronomical books for additional reading.

This excellent book will encourage and inspire the amateur skyshooter to get more fun and bigger game from his hunting.

MERWYN G. UTTER.
Smithsonian Observatory on Table Mountain, Wrightwood, California.

Berliner Astronomisches Jahrbuch 1950. (Akademie-Verlag GMBH, Berlin.) This large-sized volume of more than 400 pages has recently been published. It is the 175th in the series of annual volumes of this kind. Moreover it is the outgrowth of earlier similar publications dating back to 1700. As the title indicates, this volume is the German counterpart of the British *Nautical Almanac*, the *American Ephemeris*, and the French *Connaissance des Temps*. Other countries have corresponding publications, but those mentioned are the best known among them. It therefore contains numerous tables of data relating to the sun, moon, planets, and stars, and also much additional astronomical information.

An international agreement, established in 1911, is again in effect. By this agreement the several parts that are common in the various year books are prepared by one of them and furnished to the others, thus avoiding duplication of work. The volume before us was prepared by the Astronomisches Recheninstitut in Berlin and in Heidelberg under the direction of Dr. A. Kopff. —C.H.G.

Scientific Autobiography and Other Papers, by Max Planck. Translated from the German by Frank Gaynor. (Published by The Philosophical Library. 1949. 188 pages. $3.75.)

The author of this collection of popular lectures is doubtless well known to most readers of this journal. His formulation of the quantum theory has placed him in a position of such outstanding preeminence that this informal statement of his views on the problems of science is bound to be of interest to a large public in this country as well as in Europe. The lectures apparently were written for people like those who in our own country pore over the popularizations of Eddington and Jeans. Like these masters, Planck was concerned with the intelligent but not technically trained layman who wants to have stated in language he can understand what the upshot of the scientist's work is, and some explanation of its bearing on religious faith. The book is made up of a Memorial Address by Max von Laue, and the following papers by Planck himself: A Scientific Autobiography, Phantom Problems in Science, The Meaning and Limitations of Exact Science, The Concept of Causality in Physics, and Religion and Natural Science.

In the introductory essay the author sketches the development of his own intellectual life. Of particular interest here is his account of his relations with Helmholtz, Ostwald, and Einstein. In Phantom Problems (Scheinprobleme) of Science he points out that in many apparently insoluble situations light breaks

when we recognize, as in the mind-body problem, that the physical and the mental are the self-same processes viewed from two diametrically opposite directions. In his lecture, The Meaning and Limits of Exact Science, Planck takes up the cudgels with the Logical Positivists. Science, he maintains, is concerned with the understanding of the world as it is revealed to us by our sensations. On this point he would agree with the positivists. But he goes beyond them in his belief in a real or metaphysical world existing outside the range of sensations. He is convinced of the existence of such a world by the presence of universal constants in nature, and by the consideration that the elements in the order of nature appear to be mutually interlinked according to one uniform plan. Thus natural science exhibits a rational world order, the inner essence of which remains completely unknown to us. Planck's phenomenalism gives a clue to his philosophy of religion whose outlines he sketches in the final essay in the book. Religion, he teaches, is based on man's humility before the supernatural power to which all life is subject. Religion penetrates the phenomenal world by the use of its own peculiar symbols which point beyond themselves to a metaphysical reality. The arguments which Planck gives for his belief in the existence of this realm are carefully thought out, clearly stated, and are worthy of the most careful study.

RICHARD G. DOUGLAS.

Northfield, Minnesota.

Gaseous Nebulae and Novae, by Voronzov-Veliaminov. (Moskva-Leningrad, 1948. 584 pages.)

1. A reviewer is at liberty to select any aspect of the book under consideration. He might choose some interesting side lights, which from the point of view of the author are of secondary importance. For example the reviewer might indulge himself in discussing the dedication of the book. Or he could dwell upon some passages in the book that portray the author not so much as a scientist but as a personality. But however attractive such excursions might appear to be, I believe that they are not essential to a review of any book of general scientific value. And such book is now before us.

2. The book is a textbook for the students in Russian Universities. After a short introduction, a comprehensive chapter (I) on O stars represents the vanguard of the attack. Although the author says that there is no scientist in existence who is "Top-notch" in all branches of the problem, the book evinces plenty of theoretical and observational knowledge which, if it does not contradict, at least challenges this assertion. Chapter I contains much useful information but the masses of O stars are discussed in a conventional way by means of mass functions: a treatment which, though often used, gives a misleading idea about the masses of the stars. At the end of the chapter the author clings still to the old (though never firmly intrenched) idea of continuous ejection from the surface of Wolf-Rayet stars.

3. The problem of "Diffuse Nebulae" is treated in Chapter II, together with the interstellar medium. The presentation is clear, not particularly original. The final remark deserves attention; "The mass of the matter in a diffuse state is smaller than that in the stars, or the gaseous (stellar) mass is about ten times larger than that of dust."

3. Chapter III is called "Planetary Nebulae." Here more than in previous chapters the author presents much of his own material, especially his photometric investigations on NGC 6572, 6720, and 6853.

Few books wait long enough, and often they cannot be delayed; but if it had been otherwise with this one the sections on the rotation, expansion, and distribution of planetary nebulae would have received a fresh impulse, due to the new and striking observational results obtained at Mount Wilson and Palomar observatories. Interesting is the conclusion of Parenago, quoted by Voronzov-Veliaminov, that up to the present we have discovered only 2% of all the planetary nebulae in our Galaxy.

4. The following chapter, IV, is given to the physical and theoretical side of the problem. It is a heavy section and the student or specialist will find in it excitement if not merriment. It embodies discussions on mechanism, intensities, stratification, physical conditions for producing electron densities, etc. It concludes with a detailed discourse on the temperatures of planetary nebulae.

5. The following chapters, V and VI, are in my opinion the cream of the book. In the first chapter the observational material is emphasized while the second accentuates the interpretative and physical character of the problem. As in other chapters some of the author's work is included. Both chapters are written lucidly, rather engaging, and often with the sparks of erudition that are typical of the author. There is a charming remark about the discovery of the outburst of T Coronae Borealis by an amateur astronomer in Siberian Taiga, who had "waited" for this outburst (April 8, 1946)* for many years! There is also some useful scientific humor in his remark how the American word "recurrent" might be translated into Russian. It has of course nothing to do with "vosvratny" as V. V. rightly points out. Novae are universally acknowledged as the most fascinating astronomical objects. No scientist can help being completely enraptured on entering the gorgeous labyrinth of Nova research; it happens to every one. But then comes the inevitable: loss of balance. We find it here. The chapters on Novae contain an overemphasis on general regularities and laws. It is known that no two novae are fully alike, yet the author spends many pages in presenting schematised correlations between spectral phenomena and light curves. In the opinion of the reviewer such idealized correlations are at the most of a descriptive value. Only a simultaneous grasp of spectral development, velocity changes, and light curves can lead to a complete understanding of the Nova Go-Off.

7. The seventh chapter is less conventional, collecting such heterogeneous groups of stars as Wolf-Rayet, U Geminorum, peculiar Variables of Nova-like type, P Cygni, and Be stars.

8. Chapter VIII (small in consideration of existing material) is written on Supernovae.

9. Then comes the final chapter, containing 25 pages and dealing with "Origin and Evolution of Novae and Gaseous Nebulae." Here the author begins with his own ideas on the so-called "White-Blue" sequence of hot stars. Their spectra lie between "Continuum," O and B0 and their absolute magnitude range from -3 to $+10$. To this group belong the Wolf-Rayet stars, nuclei of planetary nebulae, and novae at minimum. On the causes of Nova outbursts the author joins the group that believes in external, not in internal causes.

The last chapter is followed by an extensive, probably complete, index of literature, comprising over 1260 references and by a diverse set of photographic reproductions covering 48 pages which are rounded up by a catalogue of planetary nebulae, galactic novae, and supernovae.

*This is an error: the outburst took place in February.

The book is well bound and has excellent paper but the photographic reproductions do not rise to the same heights. The book can be recommended to student and specialist all over the astronomical world. For some non-Russians it would be worthwhile to learn the Russian language, at least for the satisfaction of reading their own researches described in Russian. Many investigations made in the United States are used in the book, and the corresponding diagrams are freely reproduced.

SERGEI GAPOSCHKIN.

Harvard College Observatory, October, 1949.